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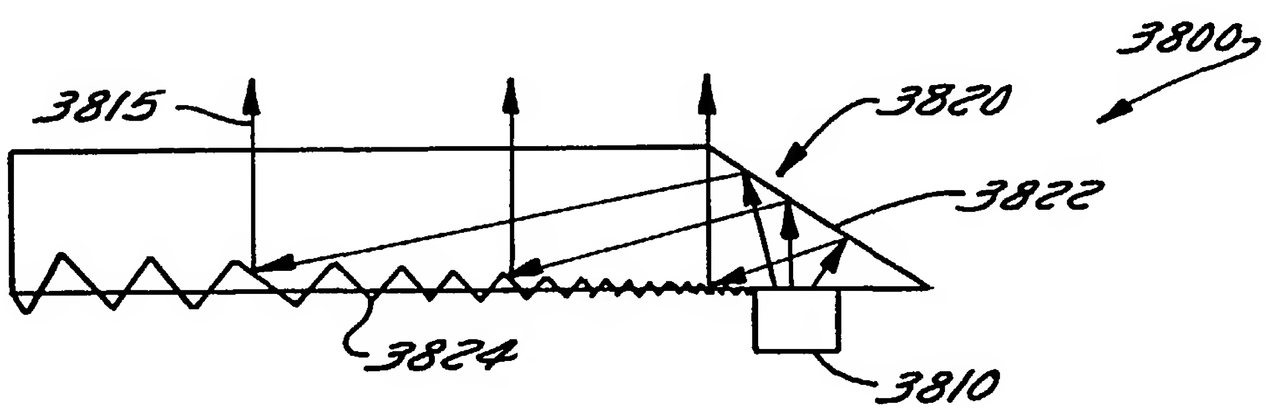
(54) Title: SCANNER UTILIZING LIGHT PIPE WITH DIFFUSER



(57) Abstract: A scanner that can include a light source (3810) emitting light through a light pipe (3820) to a detector array. The light pipe can include a reflective surface (3822) and a diffuser (3824). The reflective surface can reflect light (3815), directly or indirectly towards the diffuser and the diffuser can diffuse the light out of the light pipe. The light pipe can further include a reflective groove that reflects ligth from the reflective surface towards the diffuser. The diffuser can diffuse the light to an object that reflects the light to the detector array. The object may be a bar code, paper money, or any other object that can be scanned. The diffuser may be a variable diffuser.

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Scanner Utilizing Light Pipe with Diffuser

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is directed to a scanner and more particularly to scanners that include light shaping variable diffusers incorporated in light pipe systems.

2. Description of Related Art

Presently, conventional scanning systems, such as bar code recognition systems, use point source illumination, such as light emitting diodes (LEDs) and point reading. These systems often include bar code illuminators that scan along a series of bar codes. Such bar code illuminators can be used in hand held housings that can be swept back and forth across a bar code until the bar code is processed by a detector system in the bar code recognition system. Alternatively, the bar code illuminator can be placed in a stationary system and the bar code itself can be moved back and forth across the bar code illuminator until the detector system processes the bar code.

Unfortunately, such bar code illuminators require bulky housing and fixturing. In the case of laser scanner illuminators, such systems require moving mechanical parts, such as vibrating or rotating mirrors and collecting optics. Another disadvantage of laser scanners is an eye safety problem that can be hazardous to a users of the laser scanner.

A diffuser can be useful in scanning systems. Unfortunately, present diffusers only diffuse light at one diffusion angle. In particular, present diffusers do not gradually vary the diffusion angle across an axis of the diffuser. Furthermore, present diffusers do not gradually vary the diffusion angle depending on a location on the diffuser.

There is also presently a failure to recognize the usefulness of diffusers in various applications. For example, there is a failure to recognize the usefulness of a diffuser in a scanner application. Additionally, there is a failure to recognize the usefulness of diffusers in other applications, such as encoders and sensors.

Current encoders can be used to encode data that represents the position or movement of an object. These encoders can be used, for example, on steering wheels in automobiles to count the number of revolutions a steering wheel is turned. These encoders can also be used, for example, on DC motors and other motors that have linear states for robotic applications where objects are moved with extreme precision. In such an application, the encoder can be used to calculate the number of turns that a motor makes to determine the distance that a shield has moved.

Unfortunately, such encoders are relatively bulky and take up excessive space in a system in which they are employed. For example, such encoders cannot be employed in a relatively planar manner.

A similar problem exists for scanners, such as scanners used in barcode readers. Because of the need for light projection and focusing, current scanners take up excessive space in systems and housings in which they are employed. For example, such scanners, like the encoders, cannot be employed in a relatively planar manner.

SUMMARY OF THE INVENTION

The present invention provides a scanner. The scanner can include a light source emitting light to a light pipe and a detector array. The light source can emit light through the light pipe to the detector array. The light pipe can include a reflective surface and a diffuser. The reflective surface can reflect light, directly or indirectly towards the diffuser and the diffuser can diffuse light out of the light pipe. The light pipe can further include a reflective groove that reflects light from the reflective surface towards the diffuser. The diffuser can diffuse the light to an object that reflects the light to the detector array. The object may be a bar code, paper money, or any other object that can be scanned. The diffuser may be a variable diffuser.

The variable diffuser can include a holographic medium and a diffusion pattern that gradually varies in diffusion angle across the holographic medium so that the variance in diffusion angle is imperceptible to the naked eye. The diffusion pattern can include many diffusion patterns with different angles, the diffusion patterns overlapping each other to create a gradually varying diffusion angle. The diffusion patterns may overlap each other by 10 percent of the area of each diffusion pattern and the diffusion patterns may vary across an axis of the holographic medium.

A variable diffuser master may be used to create the variable diffuser. The variable diffuser master can be created by a system using a light source that projects light, a mask located in the path of the light projected from the light source and an opening in the mask, the opening being variable in size and the opening passing light through the mask. The system can include a plate where the opening in the mask passes light through the mask to the plate and the light source can project light through the opening in the mask onto sequential overlapping portions of the plate. The system can also include a blocker that blocks some of the light projected from the light source. The system can further include a first shield with an opening in the path of the light and a second shield with an opening located in between the mask and the plate. The distances between and the sizes of the components of the system can be varied as sequential light projections are made onto the plate in order to achieve gradually varying diffusion patterns on the plate. This plate with gradually varying diffusion patterns can be used to create a variable holographic diffuser with such a pattern so that variances between varying diffusion patterns are imperceptible.

The variable diffuser may also be used in a device for sensing light or a sensor. The sensor can include a waveguide, a light source, a device for collimating light and a light detector. The device for collimating light may be a collimating lens and the waveguide can preserve the collimation of the light. The device for collimating light may also be a variable diffuser located within the waveguide where the variable diffuser collimates the light before the light exits the waveguide. The light source and the detector may both be located on the same side of the waveguide on a printed circuit board. An encoder can be located in between the waveguide and the detector. The waveguide can include metalized ends and a side containing facets.

By using the variable diffuser and/or waveguides and light pipes in sensors and scanners, the sensors and scanners can be reduced to sizes that were not obtainable without the use of variable diffusers and light pipes. Additionally, improved accuracy of scanning and sensing can be obtained through the use of variable diffusers and light pipes due reduced size and more precise diffusion patterns. Furthermore, more visually accurate displays can be obtained through the use of variable diffusers because variations between different diffusion angles are imperceptible.

BRIEF DESCRIPTION OF THE DRAWINGS

The preferred embodiments of the present invention will be described with reference to the following figures, wherein like numerals designate like elements, and wherein:

Fig. 1 is an exemplary illustration of a method of manufacturing a variable diffuser;

Fig. 2 is an exemplary illustration of a plate;

Fig. 3 is an exemplary illustration of a mask;

Figs. 4-7 are exemplary illustrations of varying widths of a slit on a mask;

Fig. 8 is an exemplary illustration of overlapping diffusion patterns;

Fig. 9 is an exemplary illustration of a direction of movement of a plate;

Fig. 10 is an exemplary illustration of various diffusing patterns;

Fig. 11 is an exemplary illustration of a direction of movement of a plate;

Fig. 12 is an exemplary illustration of various diffusing patterns;

Figs. 13-16 are exemplary illustrations of varying widths and heights of a slit;

Fig. 17 is an exemplary illustration of diffusion patterns;

Fig. 18 is an exemplary illustration of a direction of movement of a plate;

Fig. 19 is an exemplary illustration of diffusing patterns;

Fig. 20 is an exemplary illustration of a direction of movement of a plate;

Fig. 21 is an exemplary illustration of diffusing patterns;

Fig. 22 is an exemplary diagram of a system for manufacturing a variable diffuser;

Figs. 23-26 are exemplary illustrations of varying dimensions of a slot and a blocker;

Fig. 27 is an exemplary illustration of resulting diffusion patterns on a plate;

Fig. 28 is an exemplary illustration of a symmetric variable diffuser;

Fig. 29 is an exemplary illustration of an asymmetric variable diffuser;

Fig. 30 is an exemplary illustration of a variable diffuser in a backlight display;

Fig. 31 is an exemplary illustration of a sensor;

Fig. 32 is an exemplary illustration of a sensor according to another embodiment;

Fig. 33 is an exemplary illustration of a sensor according to another embodiment;

Fig. 34 is an exemplary illustration of a bar code scanner;

Fig. 35 is an exemplary illustration of a scanner according to another embodiment;

Fig. 36 is an exemplary illustration of a scanner according to another embodiment;

Fig. 37 is an exemplary illustration of a scanner according to another embodiment;

Fig. 38 is an exemplary illustration of a light pipe system;

Fig. 39 is an exemplary illustration of a light pipe system according to another embodiment;

Fig. 40 is an exemplary illustration of a light pipe system; and

Fig. 41 is an exemplary illustration of a light pipe system according to another embodiment.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Fig. 1 is an exemplary diagram of a system 100 for manufacturing a variable diffuser or a variable diffuser master plate according to a first embodiment. The variable diffuser master may be used to create subsequent variable diffusers on holographic mediums by imprinting a pattern on the variable diffuser master onto the holographic mediums. The system 100 can include a collimated light source such as a laser 110, an objective lens 120, a cylindrical lens 130, a mask 140 and a plate 150. All of the components of system 100 can be located along an axis x. The plate 150 may be located a distance d along axis x from the mask 140. In operation, the laser 110 may project light through the objective lens 120, the cylindrical lens 130 and the mask 140 to the plate 150 to create a diffusion or speckle characteristic on plate 150. The objective lens 120, the lens 130 and the mask 140 can be varied in size, shape, and distance from each other depending on a shape of speckle desired on the plate 150.

The cylindrical lens 130 can be varied to get a specific footprint, or diffuser angle on the plate 150. The plate 150 can be a glass plate coated with a photosensitive

or photoresistant material which may be water resistant. The distance d may be varied to obtain a specific speckle pattern.

Fig. 2 is an exemplary illustration of the plate 150 of Fig. 1. The plate 150 as well as the entire system 100 may be located on an x, y and z coordinate system. For example, the plate 150 may be located a distance d away from the mask 140 along the x axis.

Fig. 3 is an exemplary illustration of the mask 140 of Fig. 1. The mask 140 can include a first side mask 310 and a second side mask 320 located a distance w from each other. The first side mask 310 and the second side mask 320 can be used in combination to create a opening or slit 330 of width w in the mask 140. The first side mask 310 and the second side mask 320 may vary in distance from each other along the y axis of Fig. 2. In operation, the distance w between the side masks 310 and 320 can be varied to affect the distribution of light projected from the laser 110 onto the plate 150. This variance can create a variable angle of diffusion along the plate 150. For example, a larger distance w between the side masks can create a larger angle of diffusion on the pate 150. A smaller distance w between the side masks can create a smaller angle of diffusion on the plate 150.

In other words, the slit width w can be varied to control the amount of light that passes through the slit 330. A smaller width w will result in less light passing through the slit 330, which directly corresponds to the profile obtained on the plate 150. A narrower width w can create a narrower elliptical angle and a wider width w can create a wider elliptical profile.

By exposing and then moving the plate 150 and varying the width w, a variety of different angles can be recorded on the same plate. These adjustments can be made in a stepwise manner to obtain a proper distribution angle on the plate 150. Accordingly, diffusion angles can be varied in a stepwise manner so that the diffusion patterns on the plate 150 overlap. Thus, a variable diffuser can be created that has a gradual diffusion pattern, which means no perceptible break in diffusion angles.

Additionally, the plate 150 may be repositioned along any of the axes of Fig. 2 and the width w of the slit 230 may be adjusted so that when light is projected from the laser 110 onto the plate 150, the angle of diffusion can vary at different positions on the

plate 150. Furthermore, the plate 150 may be repositioned in increments so that light projected from the laser 110 overlaps in incremental positions along the plate 150 as the width w of the slit 230 is varied. This overlap along the plate 150 may result in a variance of the angle of diffusion. The resulting diffuser created on the plate 150 can then diffuse light at different angles at different positions so that the variance in diffusion angles is imperceptible to the naked eye. For example, the light projected onto the plate 150 can overlap by 10 percent of the area of the light projected onto the plate 150. Accordingly, the resulting plate is a variable diffuser that diffuses light at varying angles in a gradual manner.

Figs. 4-7 are exemplary illustrations of varying widths w of slit 230 on the mask 140. For example, the width w of slit 230 may be varied to achieve slits of width 0.2 mm, 0.5 mm, 1 mm and 3 mm as shown in Figs. 4-6 respectively. Fig. 8 is an exemplary illustration of resulting overlapping diffusion patterns 810-860 on plate 150 from the varying widths of slit 230. In operation, the plate 150 can move along the y axis while the width w of slit 230 is varied to achieve diffusion patterns 810-840.

Fig. 9 is an exemplary illustration of a direction of movement of plate 150 along the y axis as the slit 230 changes in width. According to a preferred embodiment, the plate 150 moves along the y axis horizontally incrementally, or in steps. At each incremental change, the light is projected onto the plate 150 to create overlapping or varying diffusion patterns on the plate 150. According to another embodiment, the movement of the plate 150 and the variance of the width of the slit 230 may be automated so that the slit 230 varies in width while the plate 150 is moved to create a variable diffusing pattern on the plate 150. Fig. 10 is an exemplary illustration of various diffusing patterns that may be created on plate 150. Diffusing patterns 1-4, 5-8, 9-12 and 13-16 correspond to slit widths 0.2 mm, 0.5 mm, 1 mm and 3 mm respectively.

Fig. 11 is an exemplary illustration of a direction of movement of plate 150 along the z axis as the slit 230 changes in width. According to a preferred embodiment, the plate 150 moves along the z axis vertically incrementally, in steps, or automatically as disclosed according to Fig. 9. Fig. 12 is an exemplary illustration of various diffusing patterns that may be created on plate 150 according to vertical movement.

Figs. 13-16 are exemplary illustrations of varying widths w and heights h of slit 230 on mask 140. In this embodiment, additional side masks may be used to vary the height of slit 230. For example, the width w and height h of slit 230 may be varied to achieve slits of dimensions 0.2 x 4 mm, 0.2 x 8 mm, 0.2 x 16 mm and 0.2 x 32 mm as shown in Figs. 13-16 respectively. Fig. 17 is an exemplary illustration of resulting diffusion patterns 810-860 on plate 150 from the varying widths of slit 230 according to Figs. 13-16 respectively. As the length of the slit is changed, the major angle of the diffuser is changed.

Fig. 18 is an exemplary illustration of a direction of movement of plate 150 along the y axis as the slit 230 changes in dimension. According to a preferred embodiment, the plate 150 moves along the y axis horizontally incrementally, in steps or continuously. The plate 150 may move along the y axis continuously by use of an automated system. At each incremental change, the light is projected onto the plate 150 to create varying or overlapping diffusion patterns on the plate 150. Fig. 19 is an exemplary illustration of various diffusing patterns that may be created on plate 150.

Fig. 20 is an exemplary illustration of a direction of movement of plate 150 along the z axis as the slit 230 changes in dimension. According to a preferred embodiment, the plate 150 moves along the z axis vertically incrementally, in steps, or continuously as disclosed according to Fig. 9 for proper projection of light onto the plate 150. Fig. 21 is an exemplary illustration of various diffusing patterns that may be created on plate 150 according to vertical movement.

Fig. 22 is an exemplary diagram of a system 2200 for manufacturing a variable diffuser according to another embodiment. The system 2200 can include a laser 2210, an objective lens 2220, a first shield 2230, a mask 2240, a blocker 2250, a second shield 2260 and a plate 2270. All of the components of system 100 can be located along an axis x. The first shield can include a slot 2235 and the second shield can include a slot 2265. Fig. 22 illustrates the second shield 2260 and the plate being located at various positions P1-P4 along the x axis. The system 2200 can be located on a similar coordinate system to that illustrated in Fig. 2. In operation, the laser 2210 may project light through the objective lens 2220, the first shield 2230, the mask 2240,

the blocker 2250 and the second shield 2260 to the plate 2270 to create a diffusion characteristic on plate 2270.

Figs. 23-26 are exemplary illustrations of varying dimensions of the slot 2253 and the blocker 2250 which can vary according to the locations P4-P1 respectively. For example, Fig. 26 illustrates that there may be a very large or no shield 2230 and a very small or no blocker 2250 used for position P1. The variance of resulting speckles on the plate 2270 may be created sequentially and/or overlapping and incrementally or continuously as disclosed according to the previous figures. Fig. 27 is an exemplary illustration of resulting varying diffusion or speckle patterns on plate 2270 from the varying dimensions and locations P1-P4 of the elements of system 2200. Larger circles represent larger angles.

The above-disclosed systems can be used to various types of variable diffusers that gradually change diffusion angle throughout the diffuser. A gradual change in diffusion angle means that the incremental change in diffusion angle is imperceptible to the naked eye. This gradual change is created by overlapping diffusion patterns. The gradual change may also be created by an automated continual creation of the diffusion patterns by continually moving a plate while changing at least a slit in a mask. Various types of variable diffusers that can be created can include symmetric and asymmetric variable diffusers.

Fig. 28 is an exemplary illustration of a symmetric variable diffuser 2800. The symmetric variable diffuser can have symmetrical variance in a diffusion angle along the diffuser. For example, the diffuser may vary gradually from 3 degrees at the edge of the diffuser to 20 degrees at the center of the diffuser and back to 3 degrees at the opposite edge of the diffuser.

Fig. 29 is an exemplary illustration of an asymmetric variable diffuser 2900. The asymmetric variable diffuser can have a gradual asymmetrical variance in a diffusion angle along the diffuser. For example, the diffusion angle can vary gradually from a lower angle at one end to a higher angle at another end. In another example, the diffusion angle can vary at different locations along the variable diffuser depending on the intended application of the variable diffuser.

Fig. 30 is an exemplary illustration of a variable diffuser in a backlight display 3000. The backlight display 3000 can include a variable diffuser 3010 and light sources 3020 and 3030 located at opposing ends of the variable diffuser 3010. In operation, the light sources 3020 and 3030 may provide light to the backlight display 3000. The variable diffuser 3010 can reflect light at varying angles along a vertical axis along the backlight display 3010. For example, the vertical angle may vary from 20 degrees at the center of the variable diffuser 3010 to 3 degrees at the edges of the variable diffuser 3010. Additionally, the backlight display may comprise only one light source 3020 at one edge of the variable diffuser 3010. In such an embodiment, the variable diffuser 3010 may vary a diffusion angle in an asymmetric manner along the vertical axis of the variable diffuser 3010.

Fig. 31 is an exemplary illustration of an encoder or sensor 3100. The sensor 3100 may include a light source 3110 such as an LED, light 3115 projected from the light source 3110, a collimating lens 3120, an encoder disk 3140, holes 3150 in the encoder disk 3140 and a detector 3130 such as a photodetector. In operation, the light source 3110 projects light 3115 to the collimating lens 3120. The collimating lens 3120 collimates the light 3115 for projection to the encoder disk 3140. The encoder disk 3140 can rotate about an axis of the encoder disk 3140. The detector 3130 detects the light 3115 that passes through the holes 3150 of the encoder disk 3140. When the encoder disk 3140 rotates, the detector 3130 can detect variances in the light 3115. Additionally, the holes 3150 may be aligned in a specific pattern. By aligning the holes 3150 in a specific pattern, the detector 3130 can detect variances in the light 3115 to determine the position of the encoder disk 3140. The detector 3130 can send signals to an external system to allow the system to determine when, to what extent and with what velocity the encoder disk 3140 rotates about its axis. The external system can also determine the position of the encoder disk 3140 from the signals sent from the detector 3130. The systems disclosed are not limited to encoder disks. The systems disclosed may be used with a moving sheet or any other device that may be useful in a sensor.

Fig. 32 is an exemplary illustration of a sensor 3200. The sensor 3200 may include a light source 3210 such as an LED, light 3215 projected from the light source 3210, a collimating lens 3220, a waveguide 3230 such as a holographic lightpipe, an

encoder disk 3240, holes 3250 in the encoder disk 3240, a detector 3260 such as a photodetector and a printed circuit board (PCB) 3270. The waveguide 3230 may be supported on the PCB 3270 by pins 3280. The waveguide 3230 can have ends 3233 and 3236. The ends 3233 and 3236 may be metallized in order to reflect light 3215. Additionally, the ends 3233 and 3236 may be positioned at an angle between 30 and 50 degrees from the bottom of the waveguide 3230. The light source 3210 and the detector 3260 may lie substantially in the same plane and may both be attached to the PCB 3270.

In operation, the light source 3210 projects light 3215 to the collimating lens 3220. The collimating lens 3220 collimates the light 3215 for projection through the waveguide 3230 to the encoder disk 3240 and then to the detector 3260. The waveguide retains the collimation of the light 3215 and passes the light to the encoder disk 3240. The encoder disk 3240 can rotate about an axis of the encoder disk 3240. The detector 3260 detects the light 3215 that passes through the holes 3250 of the encoder disk 3240. When the encoder disk 3240 rotates, the detector 3260 can detect variances in the light 3215 in the same manner as disclosed for sensor 3100.

Fig. 33 is an exemplary illustration of a sensor 3300 according to another embodiment where similar elements correspond to element numbers of Fig. 32. As illustrated, the sensor 3300 does not need to use a collimating lens 3220. The sensor 3300 may use a variable diffuser in the form of a variable reflector, a metalized groove or facets 3310 located within the waveguide 3230. The facets or variable diffuser may be located at the bottom 3380 of the waveguide 3230. The facets 3310 can collimate the light 3215 as it passes through the waveguide 3230. For example, the variable diffuser can be located on the bottom of the waveguide 3230 and can employ varying angles of reflection to result in a collimated light leaving the deflector to the encoder disk 3240. Additionally, the waveguide 3230 does not need to adjust the light 3215 180 degrees as illustrated. The waveguide 3230 may guide the light 3215 out the side of the waveguide 3230 so the encoder disk 3240 and the detector 3260 can be located at the side of the waveguide 3230. Furthermore, the waveguide 3230 may guide the light 3215 so that the light can be guided out of the top of the waveguide 3230 to an encoder disk 3240 and a detector 3260 located above the waveguide 3230.

The disclosed encoders may be used in, for example, automotive applications to detect, for example, the number of revolutions a steering wheel is turned. The disclosed encoders may also be used in, for example, robotics applications to determine the amount of movement of a robotic arm. Accordingly, the disclosed encoders have a wide variety of applications for any situation where it is desirable to determine the position or movement of an object.

Fig. 34 is an exemplary illustration of a scanner 3400. The scanner 3400 may include a housing 3410, light sources 3420, light 3425 emitted from the light sources 3420, lenses 3430, a focusing lens 3440 and a detector array 3450. The light sources 3420 may be surface mount light emitting diodes (LEDs). All of the components of scanner 3400 may be attached to the housing 3410 as illustrated in Fig. 34.

In operation, the light sources 3420 emit light 3425 that is projected through the lenses 3430. The lenses 3430 may have a diffraction grating which directs the light 3425 to a barcode 3460 where the light 3425 is reflected back to a focusing lens 3440. The focusing lens 3440 can focus and expand the light 3425 onto a detector array 3450. The detector array 3450 can then detect the pattern of the barcode 3460.

Fig. 35 is an exemplary illustration of a scanner 3500 according to another embodiment. The scanner 3500 can include light sources 3510, light 3515 emitted from the light sources 3510, a light pipe or waveguide 3520, a focusing lens 3530, and a detector array 3540. The light sources 3510 may be surface mount LEDs. Additionally, the light pipe 3520 can include sides that comprise a metalized surface 3522, a total internal reflection (TIR) groove 3524, and a variable diffuser 3526.

In operation, the light sources 3510 can emit light 3515 that enters the light pipe 3520. The light 3515 can be reflected off of the metalized surface 3522 to the TIR grooves 3524. The TIR grooves 3524 can reflect and redirect the light 3515 to the variable diffuser 3526. The variable diffuser 3526 can then focus the light 3515 onto an object such as a barcode 3550. The variable diffuser 3526 can be implemented so that the portion of the variable diffuser 3526 farther away from the center of the scanner 3500 redirects the light 3515 at an angle greater than the portion of the variable diffuser 3526 closer to the center of the scanner 3500. Accordingly, the variable diffuser 3526 may have a smaller angle of diffusion farther from the center of the scanner 3500 and a

larger angle of diffusion closer to the center of the scanner 3500. Therefore, the light 3515 can be more efficiently directed towards the barcode 3550. The barcode 3550 can then reflect the light to the focusing lens 3530. The focusing lens 3530 can focus the light onto the detector array 3540 where the detector array 3540 can detect the pattern on the barcode 3550.

By reducing the size of the scanner 3400 down to the size of the scanner 3500, a more compact design can be realized. Additionally, the smaller scanner 3500 can be more accurate because the light 3515 has less distance to travel before being detected by the detector array 3540.

Fig. 36 is an exemplary illustration of a scanner 3600 according to another embodiment. The scanner 3600 can include light sources 3610, light 3615 emitted from the light sources 3610, a light pipe 3620 and a detector array 3630. The light sources 3610 may be surface mount LEDs. Additionally, the light pipe 3620 can include sides that comprise a metalized surface 3622, a total internal reflection (TIR) groove 3624, and a variable diffuser 3626.

In operation, the light sources 3610 can emit light 3615 that enters the light pipe 3620. The light 3615 can be reflected off of the metalized surface 3622 to the TIR grooves 3624. The TIR grooves 3624 can reflect and redirect the light 3615 to the variable diffuser 3626. The variable diffuser 3626 can then focus the light 3615 onto a detector array 3630. The variable diffuser 3626 can be implemented so that the portion of the variable diffuser 3626 farther away from the center of the scanner 3600 redirects the light 3615 with a diffusion angle greater than the portion of the variable diffuser 3626 closer to the center of the scanner 3600. Accordingly, the variable diffuser 3626 may have a smaller angle of diffusion farther from the center of the scanner 3600 and a larger angle of diffusion closer to the center of the scanner 3600.

Fig. 37 is an exemplary illustration of a scanner 3700 according to another embodiment. The scanner 3700 can include light sources 3710, light 3715 emitted from the light sources 3710 and a light pipe 3720. The light sources 3710 may be surface mount LEDs. Additionally, the light pipe 3720 can include sides that comprise a metalized surface 3722 and a reflective variable diffuser 3724.

In operation, the light sources 3710 can emit light 3715 that enters the light pipe 3720. The light 3715 can be reflected off of the metalized surface 3722 to the reflective variable diffuser 3724. The reflective variable diffuser 3724 can reflect and redirect the light 3715 out of the light pipe 3720. In a preferred embodiment, the variable diffuser can collimate the light 3715 before the light 3715 exits the light pipe 3720. Accordingly, the variable diffuser 3724 can be implemented as a symmetric variable diffuser so that the portion of the variable diffuser 3724 farther away from the center of the scanner 3700 redirects the light 3715 with a diffusion angle greater than the portion of the variable diffuser 3724 closer to the center of the scanner 3700. Therefore, the variable diffuser 3724 may have a smaller angle of diffusion farther from the center of the scanner 3700 and a larger angle of diffusion closer to the center of the scanner 3700.

Fig. 38 is an exemplary illustration of a light pipe system 3800. The light pipe system 3800 can include a light source 3810, light 3815 emitted from the light source 3810 and a light pipe 3820. The light source 3810 may be a surface mount LED. Additionally, the light pipe 3820 can include at least one side that comprises a metalized surface 3822 and a variable diffuser 3824 in the form of a reflective variable diffuser.

In operation, the light source 3810 can emit light 3815 that enters the light pipe 3820. The light 3815 can be reflected off of the metalized surface 3822 to the variable diffuser 3824. The variable diffuser 3824 can reflect and redirect the light 3815 out of the light pipe 3820. In a preferred embodiment, the variable diffuser 3824 can collimate the light 3815 before the light 3815 exits the light pipe 3820. Accordingly, the variable diffuser 3824 can be implemented so that the portion of the variable diffuser 3824 farther away from the light source 3810 redirects the light 3815 with a diffusion angle greater than the portion of the variable diffuser 3824 closer to the light source 3810. Therefore, the variable diffuser 3824 may have a smaller angle of diffusion closer to the light source 3810 and a larger angle of diffusion farther from the light source 3810.

Fig. 39 is an exemplary illustration of a light pipe system 3900 according to another embodiment. The light pipe system 3900 can include a light source 3910 located at a side of the light pipe system, light 3915 emitted from the light source 3910,

a light pipe 3920 and a detector array 3940. The light source 3910 may be a surface mount LED. Additionally, the light pipe 3920 can include at least one side that comprises a reflective sheet such as a metalized surface 3922 and a variable diffuser 3924.

In operation, the light source 3910 can emit light 3915 that enters the side of the light pipe 3920. The light 3915 can be reflected off of the diffuser surface 3924. The variable diffuser 3924 can redirect the light 3915 out of the light pipe 3920 to the detector array 3940. Accordingly, the variable diffuser 3924 can be implemented so that the portion of the variable diffuser 3924 farther away from the light source 3910 redirects the light 3915 with a diffusion angle greater than the portion of the variable diffuser 3924 closer to the light source 3910. Therefore, the variable diffuser 3924 may have a smaller angle of diffusion closer to the light source 3910 and a larger angle of diffusion farther from the light source 3910.

Fig. 40 is an exemplary illustration of a light pipe system 4000 according to another embodiment. The light pipe system 4000 can include a light source 4010, light 4015 emitted from the light source 4010 and a light pipe 4020. The light source 4010 may be a surface mount LED and may be located at the side of the light pipe 4020. Additionally, the light pipe 4020 can include a variable diffuser 4022 in the form of a reflective variable diffuser.

In operation, the light source 4010 can emit light 4015 that enters the light pipe 4020. The variable diffuser 4022 can reflect and redirect the light 4015 out of the light pipe 4020. Accordingly, the variable diffuser 4024 can be implemented so that the portion of the variable diffuser 4022 farther away from the light source 4010 redirects the light 4015 with a diffusion angle greater than the portion of the variable diffuser 4022 closer to the light source 4010. Therefore, the variable diffuser 4024 may have a smaller angle of diffusion closer to the light source 4010 and a larger angle of diffusion farther from the light source 4010.

Fig. 41 is an exemplary illustration of a light pipe system 4100 according to another embodiment. The light pipe system 4100 can include a light source 4110 located at a side of the light pipe system, light 4115 emitted from the light source 4110, a light pipe 4120 and a light shaping diffuser 4140. The light source 4110 may be a

surface mount LED. Additionally, the light pipe 4120 can include at least one side that comprises a reflective sheet such as a metalized or total internal reflection (TIR) surface 4122 and a variable diffuser 4124.

In operation, the light source 4110 can emit light 4115 that enters the side of the light pipe 4120. The light 4115 can be reflected off of the diffuser surface 4124. The variable diffuser 4124 can redirect the light 4115 out of the light pipe 4120 through the light shaping diffuser 4140. The light shaping diffuser 4140 can than shape the light exiting the light pipe 4120. Accordingly, the variable diffuser 4124 can be implemented so that the portion of the variable diffuser 4124 farther away from the light source 4110 redirects the light 4115 with a diffusion angle greater than the portion of the variable diffuser 4124 closer to the light source 4110. Therefore, the variable diffuser 4124 may have a smaller angle of diffusion closer to the light source 4110 and a larger angle of diffusion farther from the light source 4110.

The scanners disclosed are not limited to barcode scanning. For example, the scanner 3500 can be used as a currency or bill acceptor. In operation, currency may be fed into, for example, a vending machine. The scanner 3500 can then scan the currency to validate the currency and to determine the value of the currency. In such an embodiment, the barcode 3550 of Fig. 35 can be replaced with the currency for proper operation. The detector array 3540 can be used to detect characteristics of the currency.

The variable diffusers can be used in various applications, such as elevator floor number displays, roadside signs, airport departure signs, store signs, exit signs, architectural lighting, gas station signs, automotive displays, cockpit displays, medical sensors, sensor illumination, sources for sensors in machine vision, global positioning system units, bank terminals, toys or industrial applications.

This invention is not limited to the specific combinations of elements illustrated. The elements illustrated may be interchangeable to achieve the benefits of each embodiment among the other embodiments. For example, a form of the light pipes disclosed in Figs. 37-40 may be combined with the sensor 3300 in Fig. 33 to achieve proper collimation before sending light through the encoder 3240 to the detector 3260.

While this invention has been described with specific embodiments thereof, it is evident that many alternatives, modifications, and variations will be apparent to those skilled in the art. Accordingly, the preferred embodiments of the invention as set forth herein are intended to be illustrative, not limiting. Various changes may be made without departing from the spirit and scope of the invention.

What is claimed is:

1. A device for scanning light comprising:

a light source emitting light;

a light pipe located in a path of light emitted from the light source, the light pipe including a reflective surface and a diffuser, the reflective surface reflecting the light towards the diffuser and the diffuser diffusing the light out of the light pipe; and

a detector array receiving light emitted from the light source.

2. The device for scanning light according to claim 1, wherein the light pipe further includes a reflective groove, wherein the reflective surface reflects light towards the diffuser via the reflective groove and the reflective groove reflects the light towards the diffuser.

3. The device for scanning light according to claim 1, further comprising an object, wherein the object reflects light from the diffuser towards the detector array.

4. The device for scanning light according to claim 3, wherein the object comprises at least one of a bar code, a document, a credit card, a check, a travelers check, a machine vision object and currency.

5. The device for scanning light according to claim 3, further comprising a focusing lens, wherein the focusing lens focuses the light reflected from the object towards the detector array.

6. The device for scanning light according to claim 2, wherein the light source comprises a surface mount light emitting diode.

7. The device for scanning light according to claim 1, wherein the diffuser comprises at least one of a variable diffuser and a non-lambertian diffuser in combination with prismatic structures.

8. A device for diffusing light comprising:

a holographic medium; and

a diffusion pattern that gradually varies in diffusion angle across the holographic medium.

9. The device for diffusing light according to claim 8, wherein the angle is at least one of 45° and 135°.

10. The device for diffusing light according to claim 8, wherein the diffusion pattern can comprise a plurality of diffusion patterns with different diffusion angles, the plurality of diffusion patterns overlapping each other to create the gradually varying diffusion pattern across the holographic medium.

11. The device for diffusing light according to claim 10, wherein the plurality of diffusion patterns overlap each other by about 10 percent of the area of each diffusion pattern.

12. The device for diffusing light according to claim 10, wherein the diffusion pattern varies asymmetrically across an axis of the holographic medium.

13. The device for diffusing light according to claim 10, wherein the diffusion pattern varies linearly across an axis of the holographic medium.

14. The device for diffusing light according to claim 10, further comprising at least one of an elevator floor number display, a roadside sign, an airport departure sign, a store sign, an exit sign, architectural lighting, a gas station sign, an automotive display, a cockpit display, a medical sensor, sensor illumination, a source for a sensor in machine vision, a global positioning system unit, bank terminal, machine vision, a toy and an industrial application that contains the holographic medium.

15. A system for manufacturing a variable diffuser master comprising:

a light source projecting light;

a mask in the path of the light projected from the light source; and

an opening in the mask, the opening being variable in size and the opening passing the light through the mask.

16. The system for manufacturing a variable diffuser master according to claim 15, further comprising a plate wherein the opening in the mask passes light through the mask to the plate.

17. The device for manufacturing a variable diffuser master according to claim 16, wherein the light source sequentially projects light through the opening in the mask onto overlapping portions of the plate.

18. The device for manufacturing a variable diffuser master according to claim 16, wherein the light source sequentially projects light through the opening in the mask onto overlapping portions of the plate along an axis.

19. The device for manufacturing a variable diffuser master according to claim 16, further comprising a cylindrical lens in the path of the light projected from the light source

20. The device for manufacturing a variable diffuser master according to claim 16, further comprising a blocker located on the opposite side of the mask from the light source, the blocker also being located in the path of the light projected from the light source and the blocker blocking some of the light projected from the light source.

21. The device for manufacturing a variable diffuser master according to claim 17, further comprising:

a first shield located in the path of the light projected from the light source; and

an opening in the first shield, the opening in the first shield allowing some of the light projected from the light source to pass through the opening.

22. The device for manufacturing a variable diffuser master according to claim 21, further comprising:

a second shield located on the opposite side of the mask from the light source, the second shield also being located in the path of the light projected from the light source; and

an opening in the second shield, the opening in the second shield allowing some of the light projected from the light source to pass through the opening.

23. The device for manufacturing a variable diffuser master according to claim 21, wherein the second shield is located a distance from at least one of the mask and the light source, and the distance changes with each of the overlapping portions of the plate.

24. The device for manufacturing a variable diffuser master according to claim 17, wherein the mask and the opening of the second shield change in size with each of the overlapping portions of the plate.

25. A method of manufacturing a variable diffuser master comprising:

placing a plate in front of a light source; and

sequentially emitting light from a light source onto overlapping portions of the plate.

26. The method of manufacturing a variable diffuser master according to claim 25, further comprising:

placing a mask with an opening in the mask in between the plate and the light source; and

varying the size of the opening in the mask with each sequential emission of light.

27. The method of manufacturing a variable diffuser master according to claim 26, further comprising:

placing a blocker in between the mask and the plate; and

varying the size of the blocker with at least one of the sequential emissions of light.

28. The method of manufacturing a variable diffuser master according to claim 27, further comprising:

placing an shield with an opening in the shield in between the blocker and the plate; and

varying a size of the opening in the shield with each sequential emission of light.

29. The method of manufacturing a variable diffuser master according to claim 26, further comprising varying a distance of the plate from the light source with each sequential emission of light.

30. A device for sensing light comprising:

a waveguide;

a light source located on one side of the waveguide, the light source emitting light through the waveguide;

means for collimating the light; and

a light detector detecting light provided by the light source through the waveguide.

31. The device for sensing light according to claim 30, wherein the means for collimating light comprises a collimating lens located in between the light source and the waveguide, the collimating lens collimating light provided from the light source through the waveguide, the waveguide preserving the collimation of the light as the light passes through the waveguide.

32. The device for sensing light according to claim 31, further comprising a printed circuit board, the light source and the light detector both being located on the printed circuit board.

33. The device for sensing light according to claim 30, further comprising an encoder, the encoder being located in between the detector and the waveguide.

34. The device for sensing light according to claim 33, wherein the encoder comprises an encoder disk.

35. The device for sensing light according to claim 30, wherein the waveguide has a first metalized end, a second metalized end and a side containing facets, the first metalized end located at an opposite end of the waveguide from the second metalized end.

36. The device for sensing light according to claim 35, wherein the first metalized end and the second metalized end are at an angle in the range of 30 to 50 degrees from the side containing facets.

37. The device for sensing light according to claim 30, wherein the light detector is located adjacent to the same side of the waveguide as the light source.

38. The device for sensing light according to claim 30, wherein the means for collimating light comprises a variable diffuser.

39. A device for sensing light comprising:

a waveguide;

a light source located adjacent to one side of the light pipe, the light source emitting light to the waveguide;

an encoder;

a light detector, the light detector detecting light provided by the light source through the waveguide and the encoder.

40. A device for distributing light, comprising:

light pipe; and

a variable diffuser located on the light pipe.

41. A device for scanning light comprising:

a light source emitting light;

a waveguide located in a path of light emitted from the light source, the waveguide including a reflective surface and a diffuser, the reflective surface reflecting the light towards the diffuser and the diffuser diffusing the light out of the waveguide; and

a detector array receiving light emitted from the light source through the waveguide.

42. The device for scanning light according to claim 3, wherein the object comprises at least one system of a set of systems including a bar code, a document, a credit card, a check, a travelers check, a machine vision object and currency so as to minimize the at least one system.

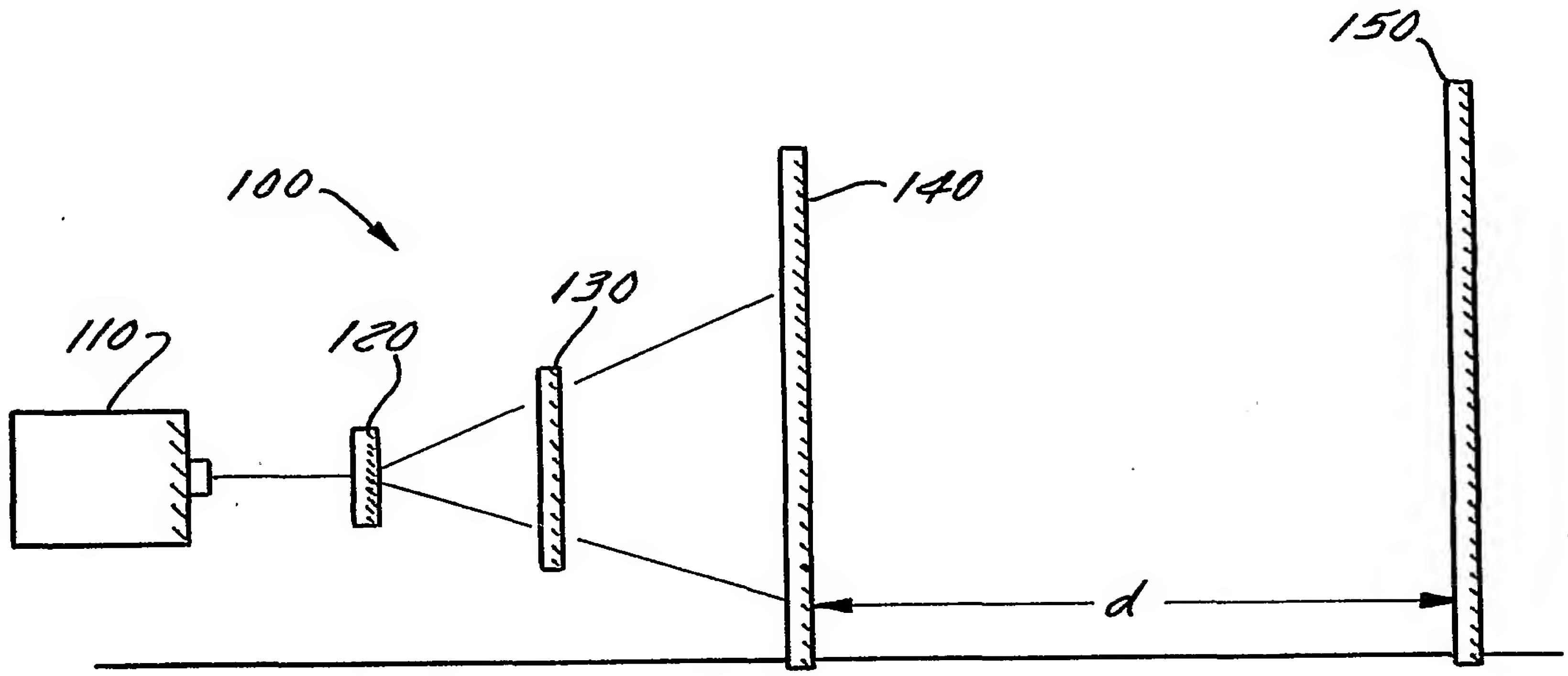


FIG. 1

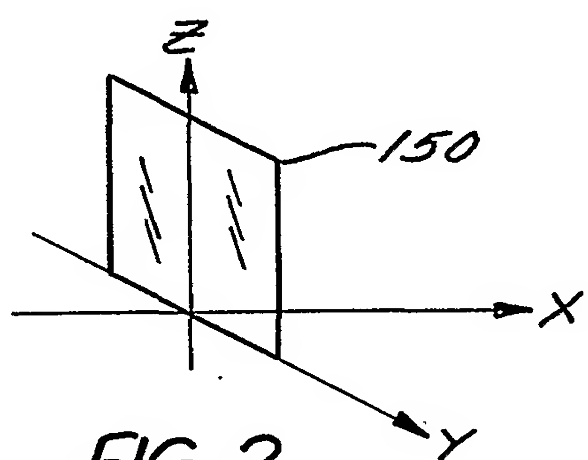


FIG. 2

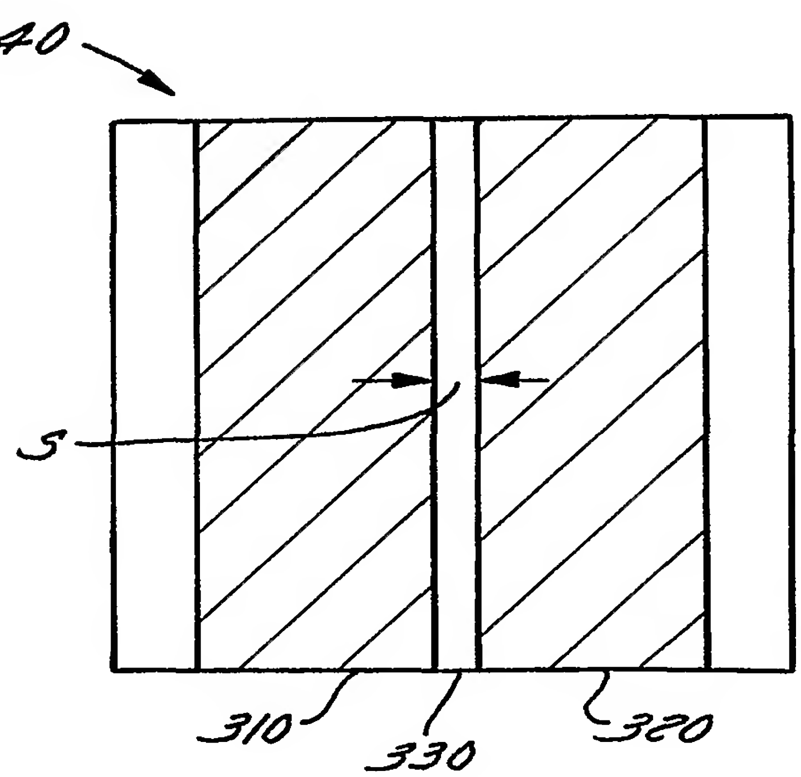


FIG. 3

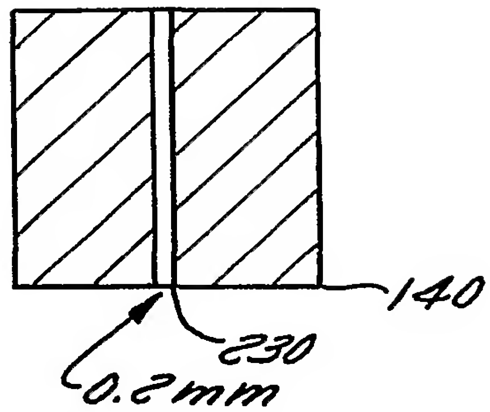


FIG. 4

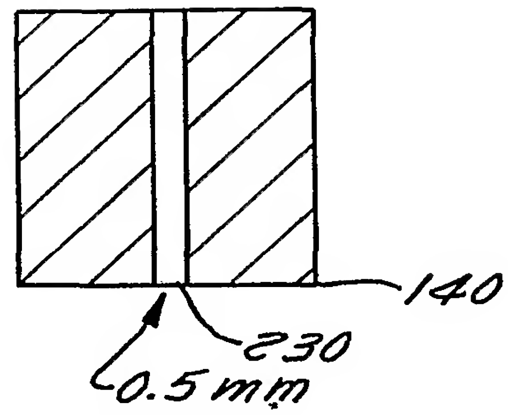


FIG. 5

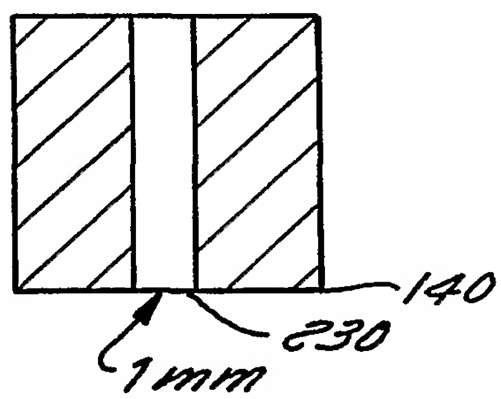


FIG. 6

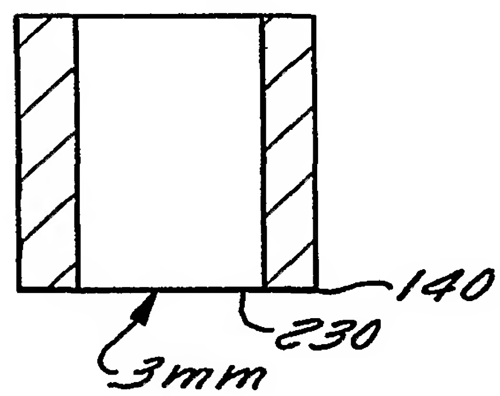


FIG. 7

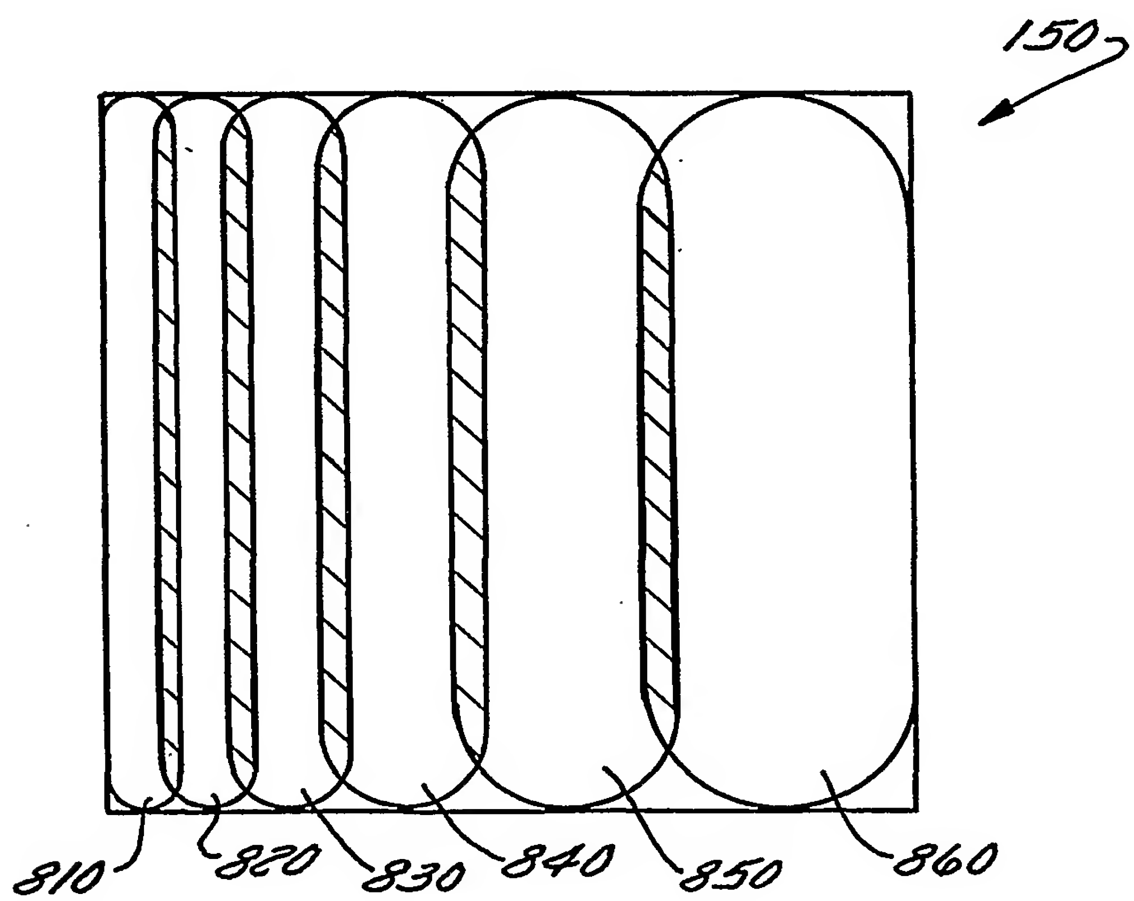


FIG. 8

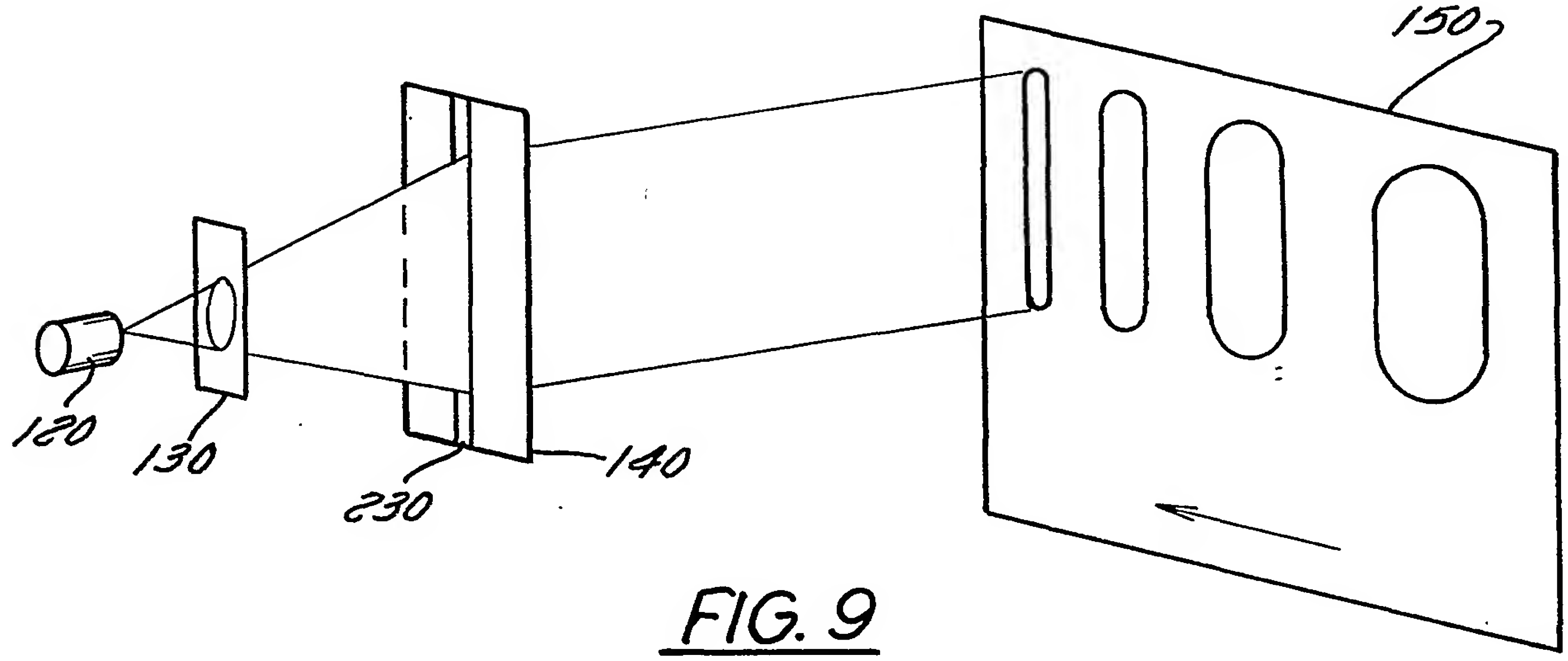

150
120
130
230
140

FIG. 9

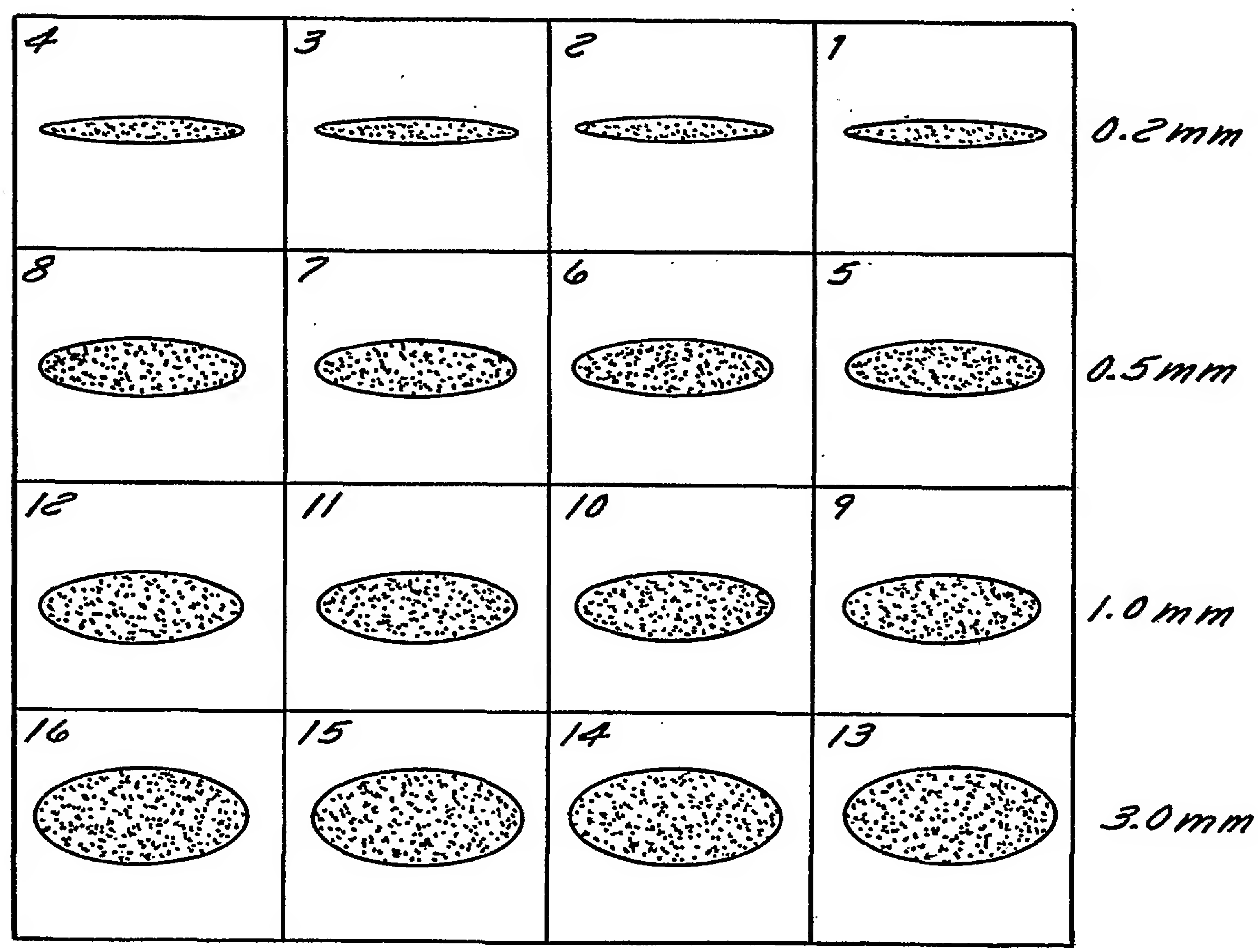

4
3
2
1
0.2mm
8
7
6
5
0.5mm
12
11
10
9
1.0mm
16
15
14
13
3.0mm

FIG. 10

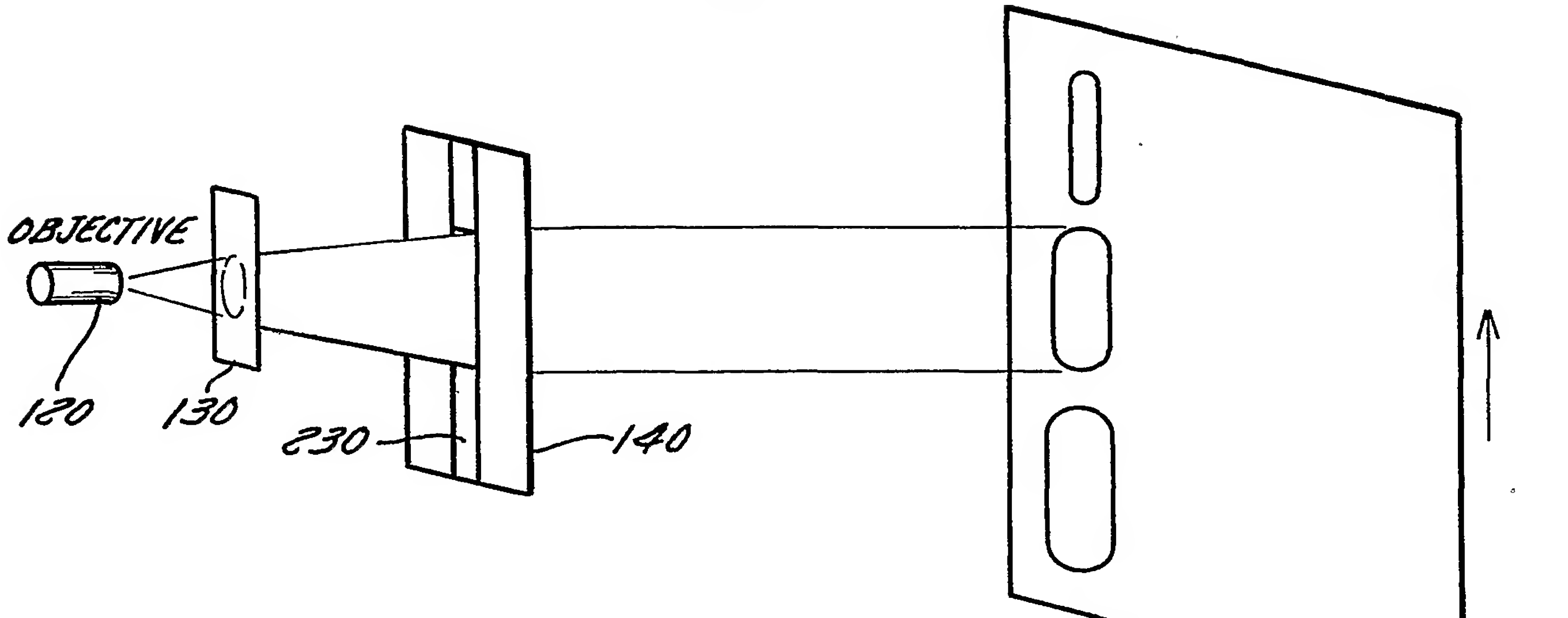

OBJECTIVE
120
130
230
140
150

FIG. 11

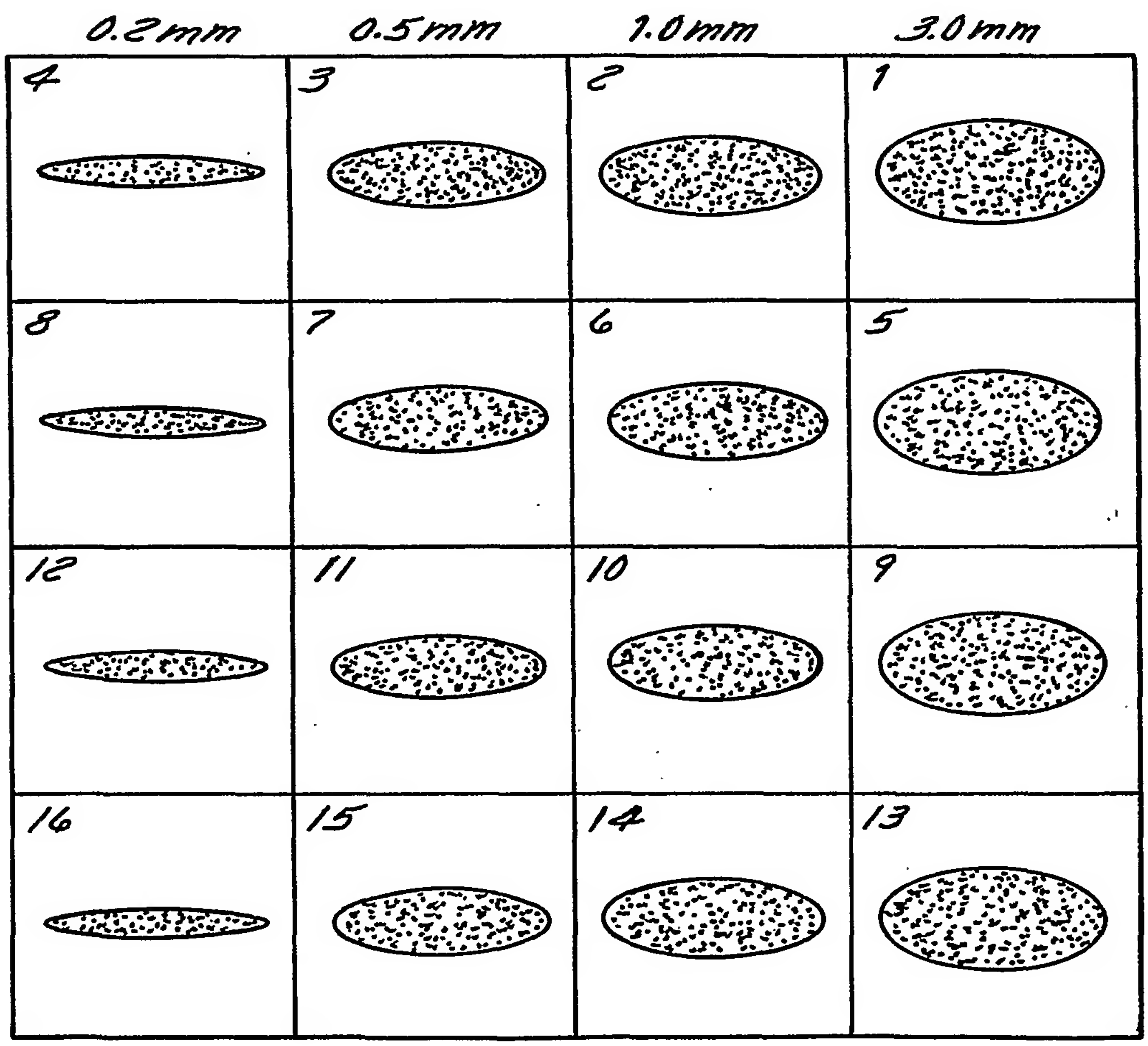

0.2mm
0.5mm
1.0mm
3.0mm
4
3
2
1
8
7
6
5
12
11
10
9
16
15
14
13

FIG. 12

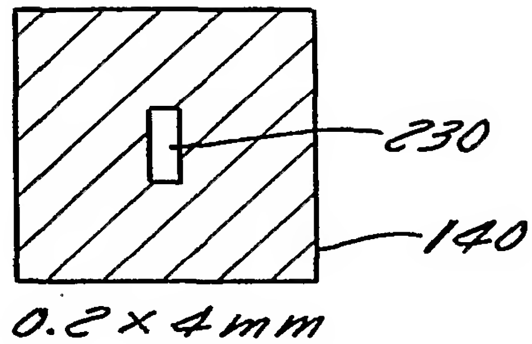


FIG. 13

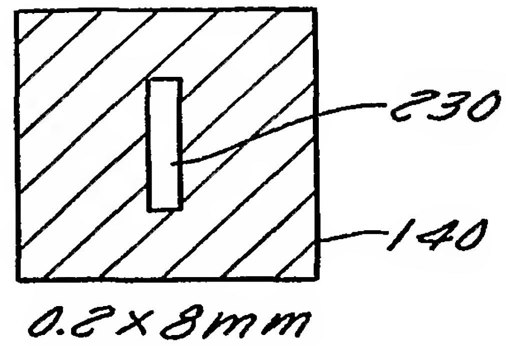


FIG. 14

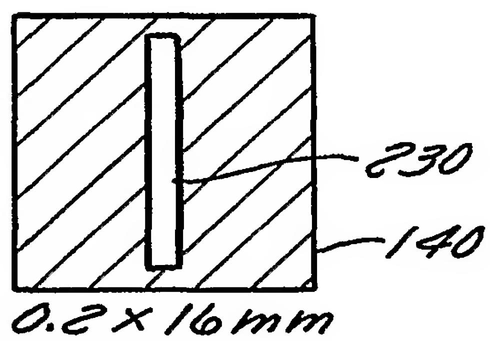


FIG. 15

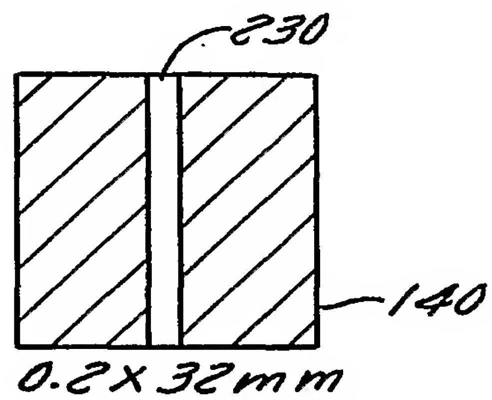


FIG. 16

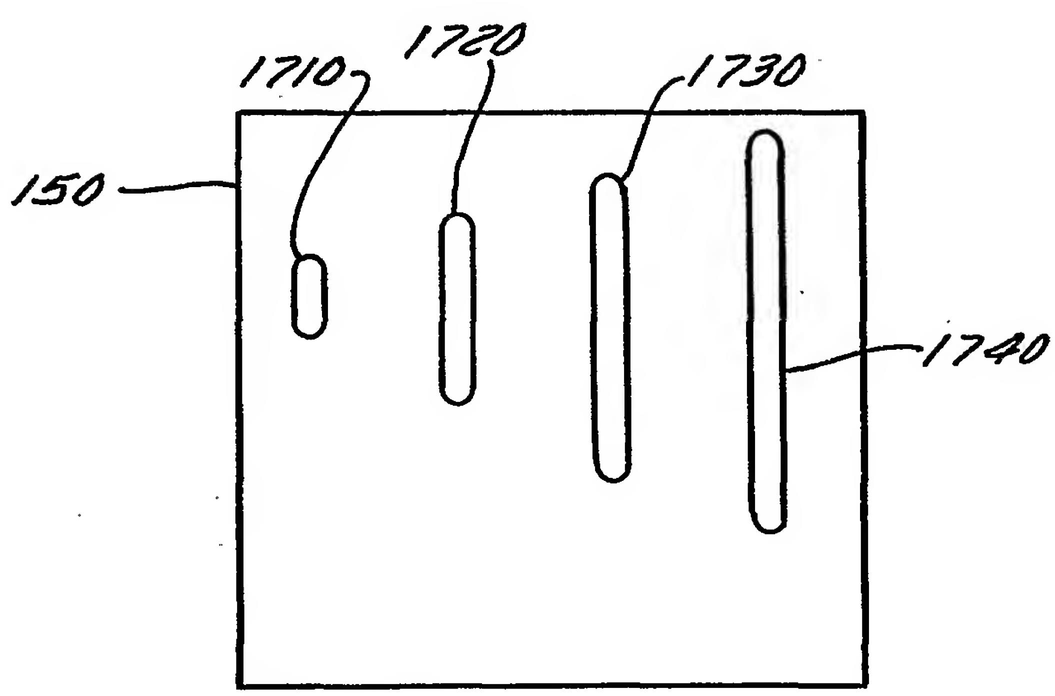


FIG. 17

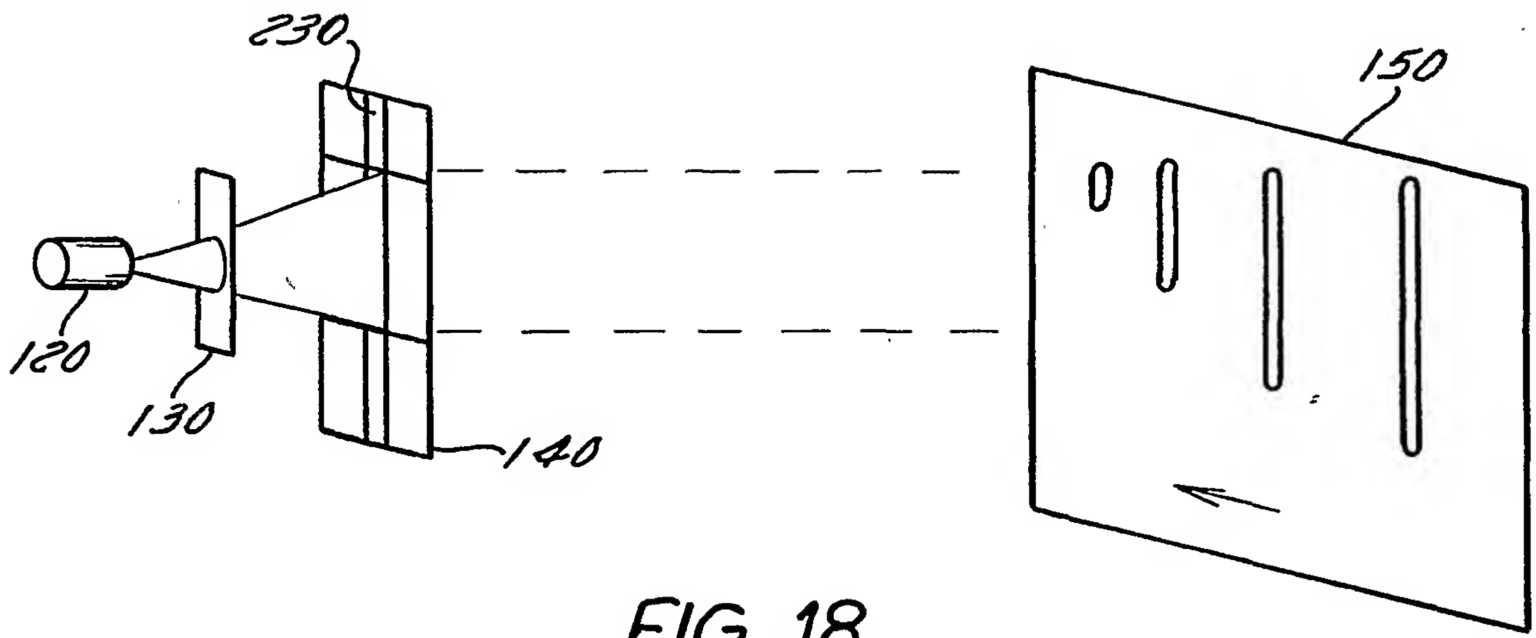


FIG. 18

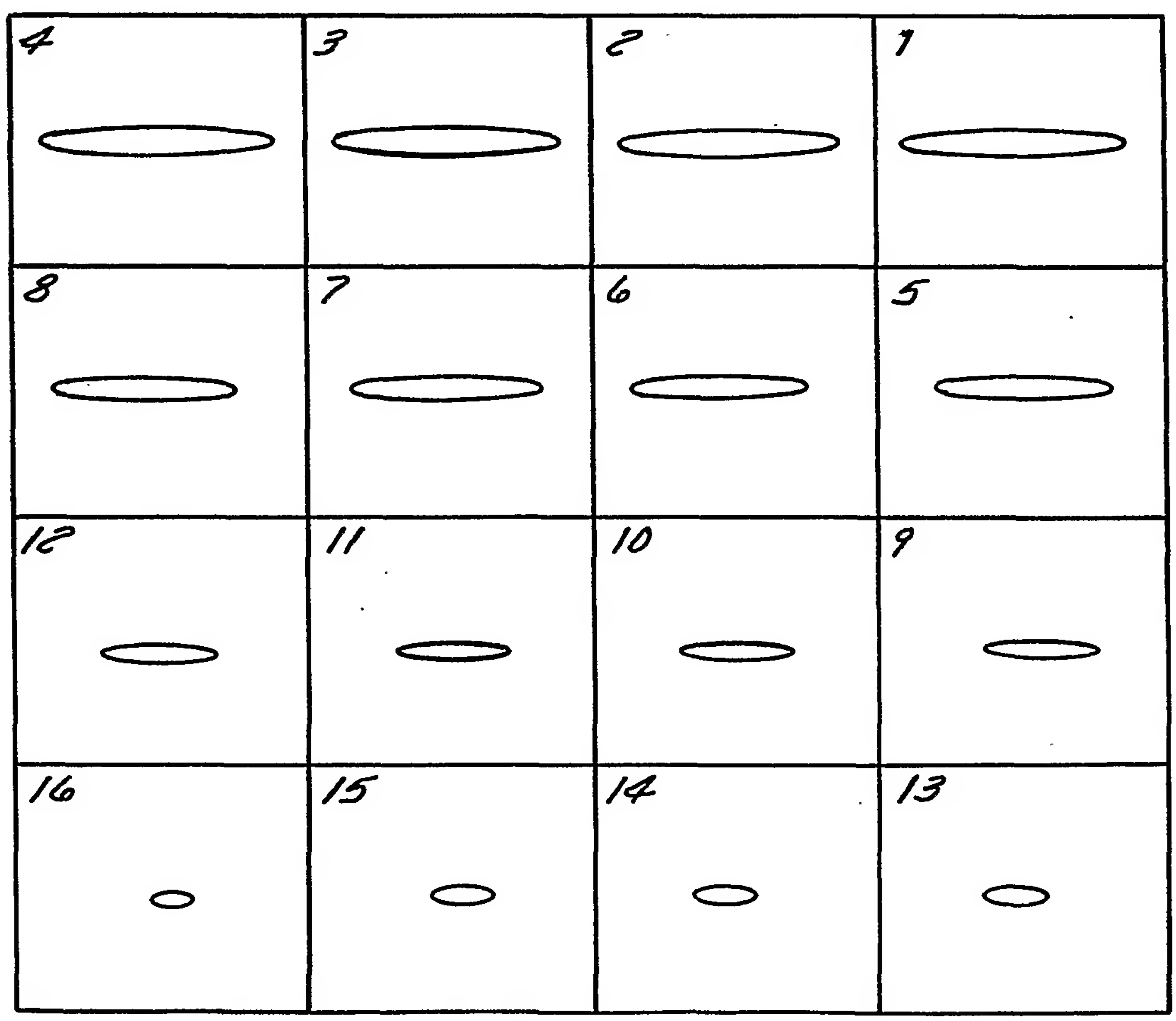


FIG. 19

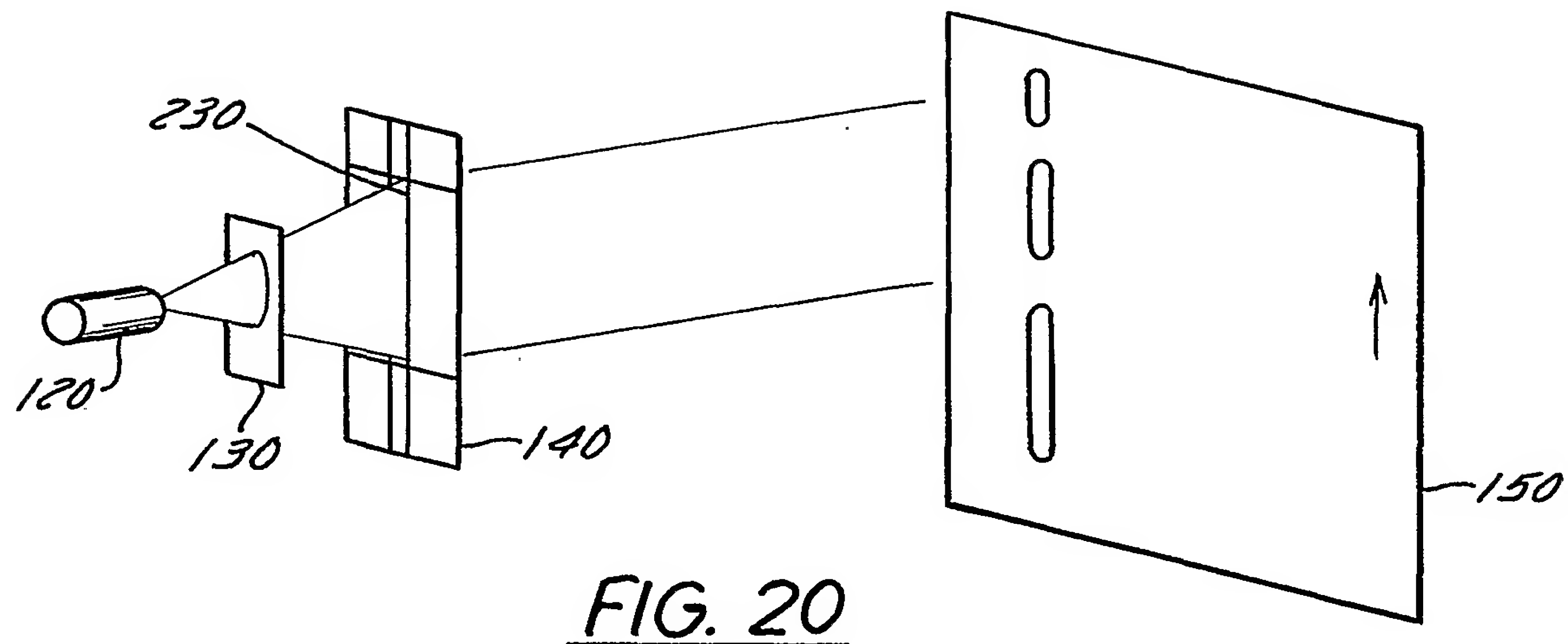


FIG. 20

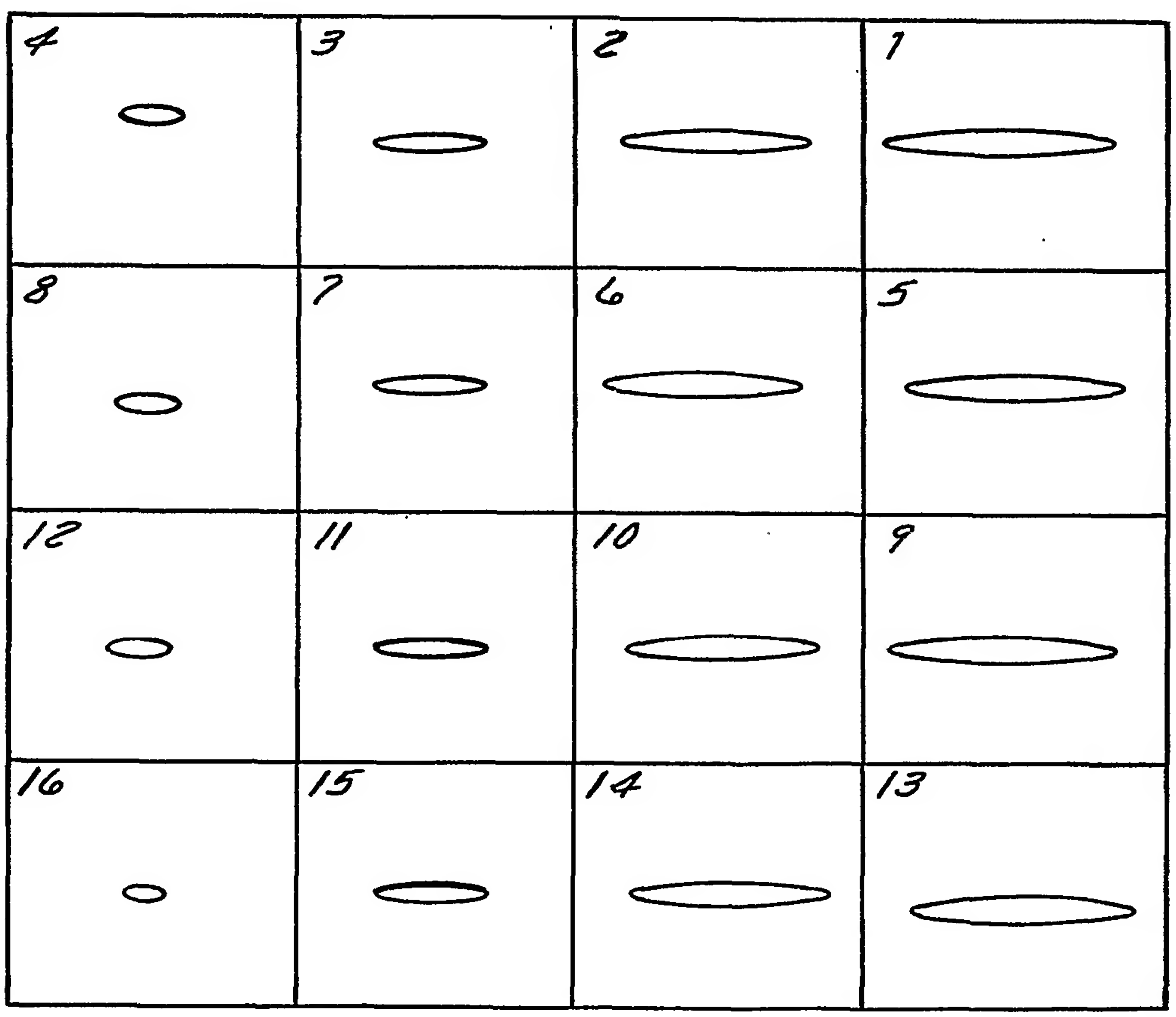


FIG. 21

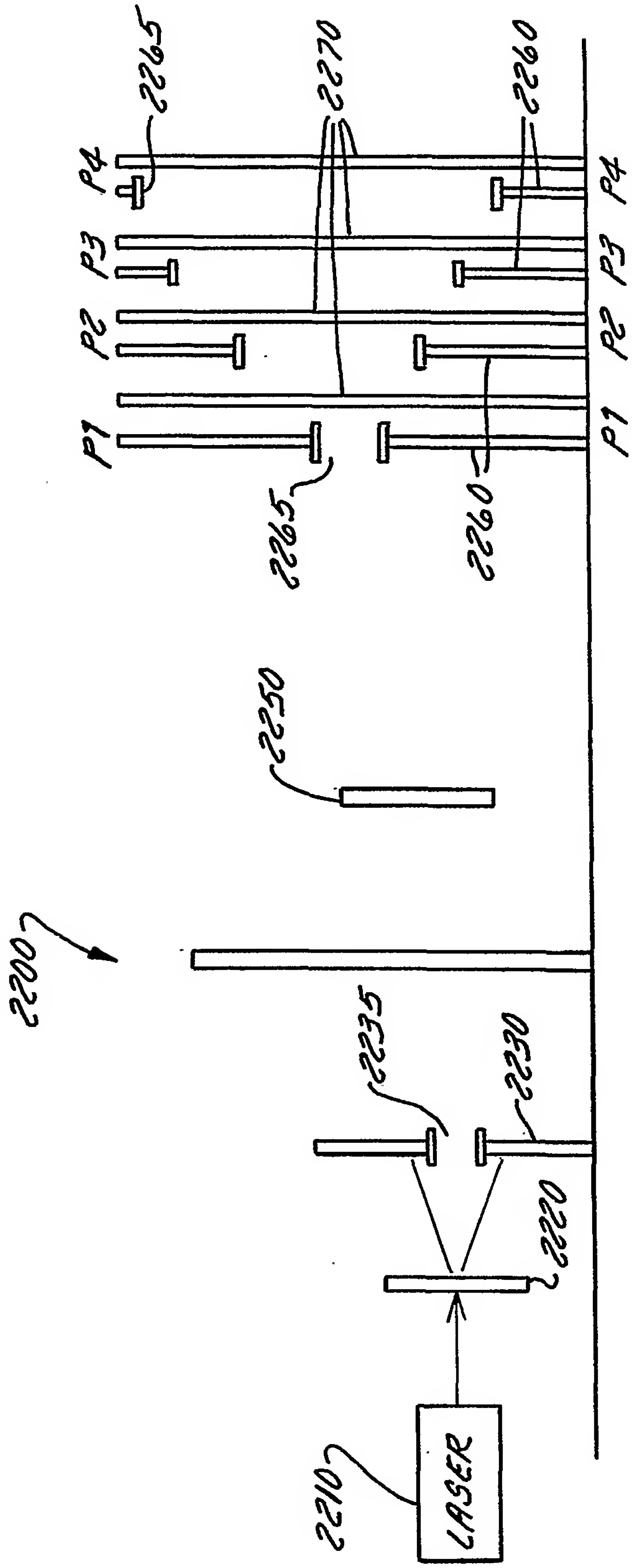

2265
2270
2260
P4
P3
P2
P1
2265
2260
2250
2200
2235
2230
2220
2210
LASER

FIG. 22

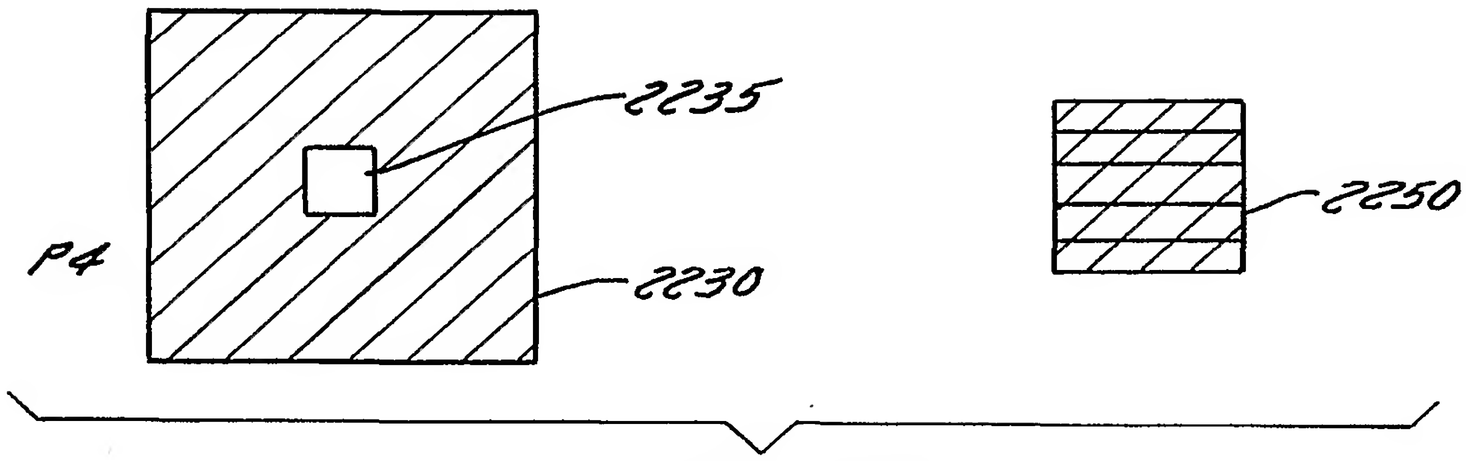


FIG. 23

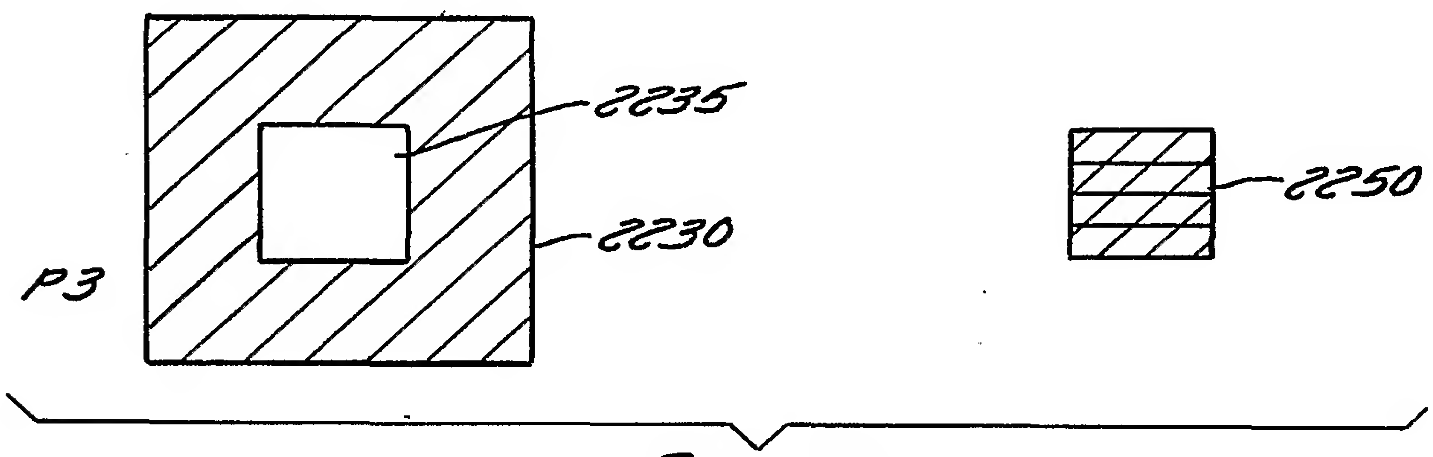


FIG. 24

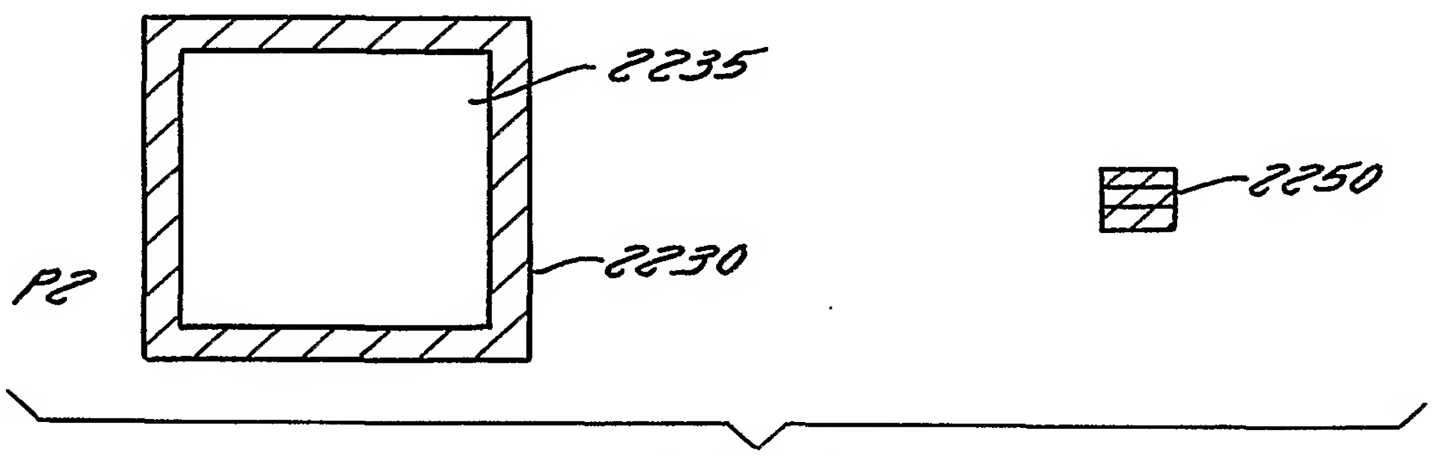


FIG. 25

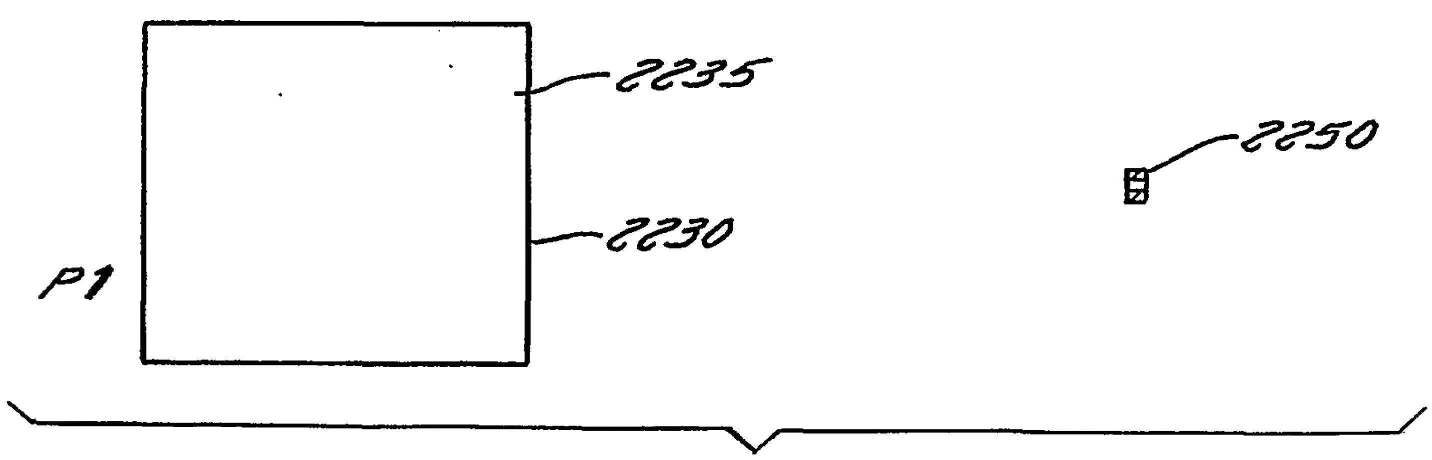


FIG. 26

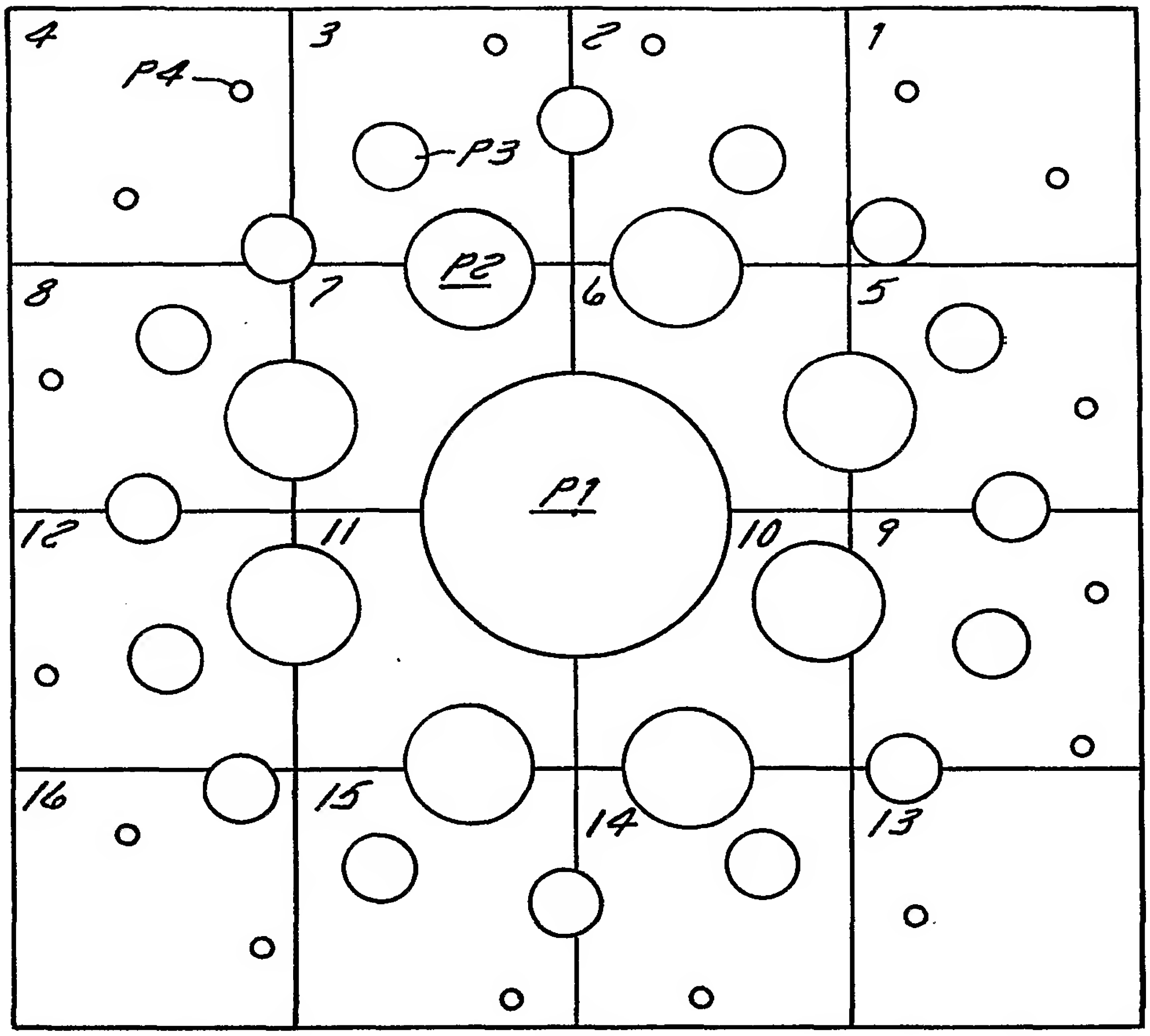


FIG. 27

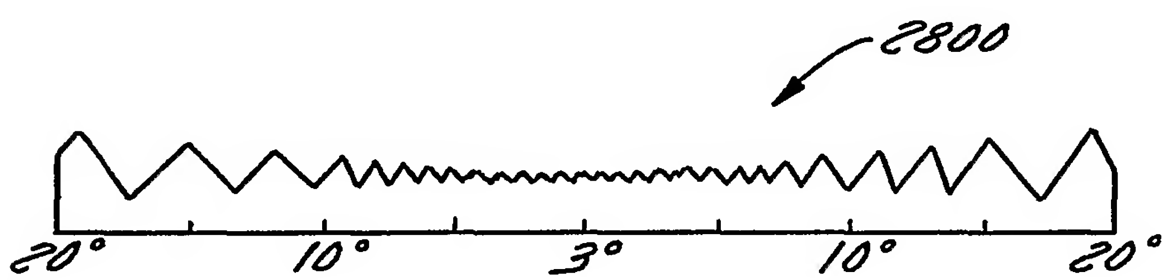


FIG. 28

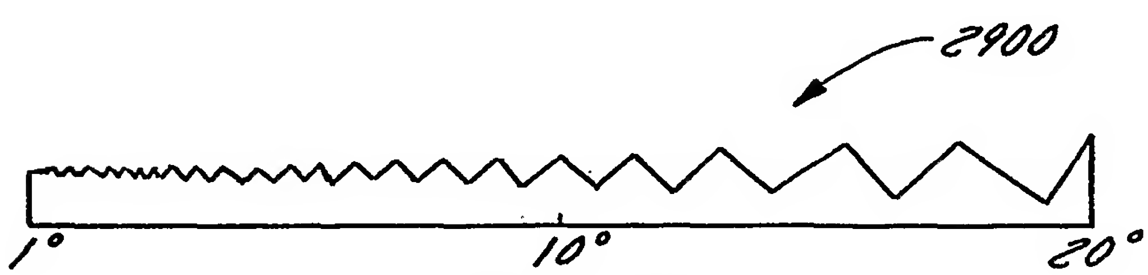


FIG. 29

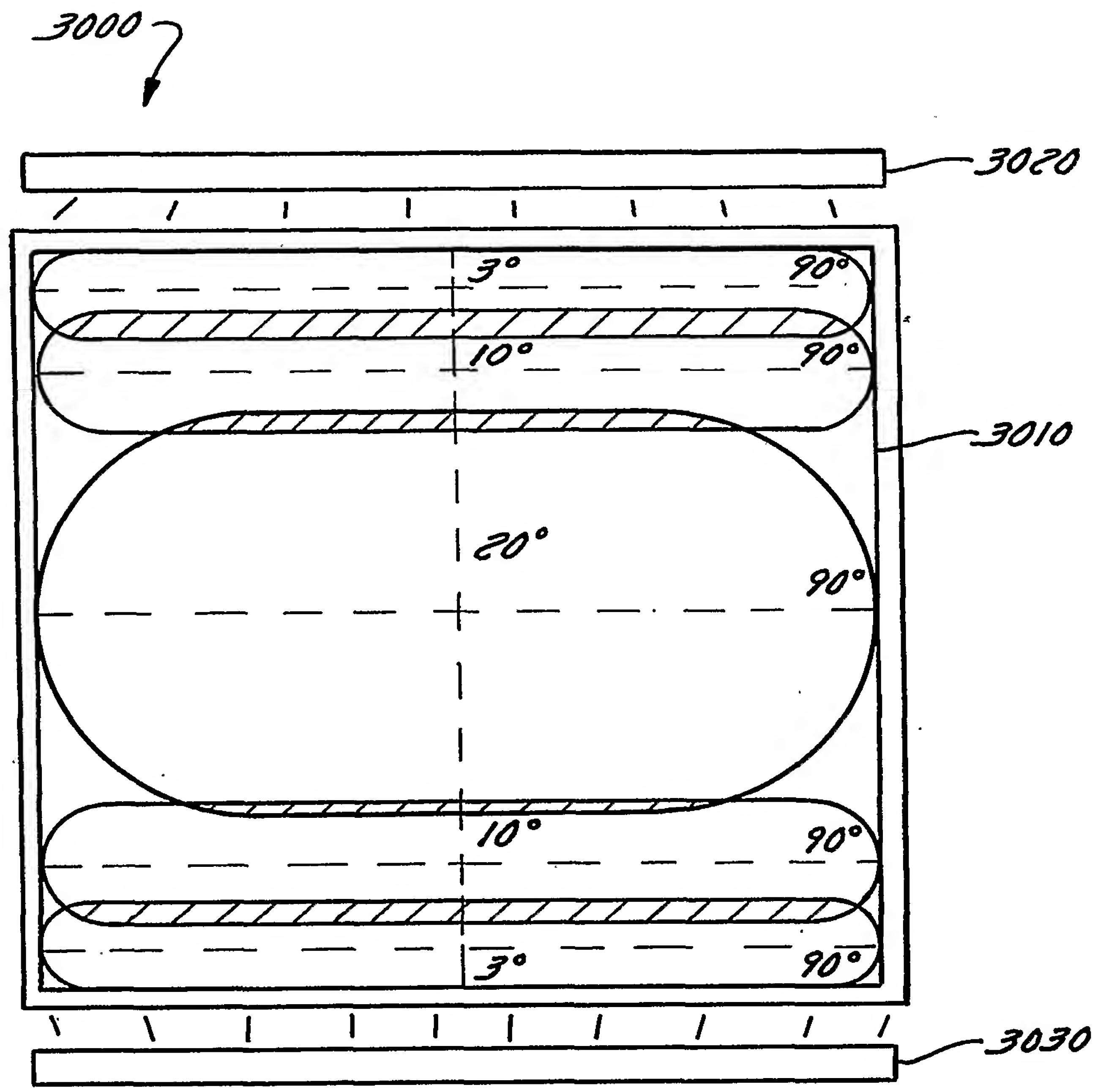


FIG. 30

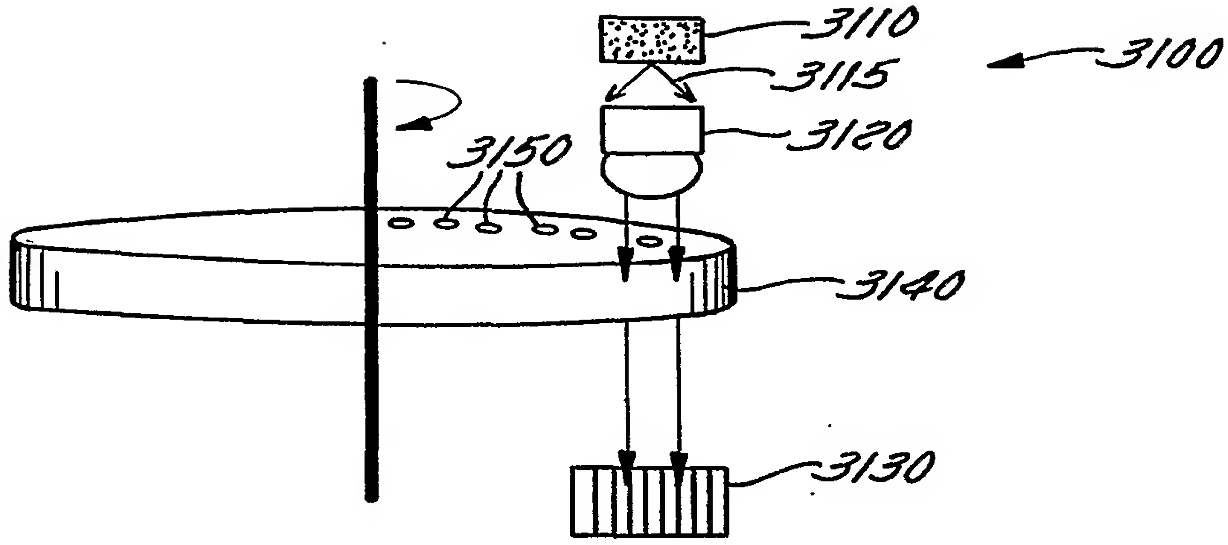

3110
3115
3100
3120
3150
3140
3130

FIG. 31

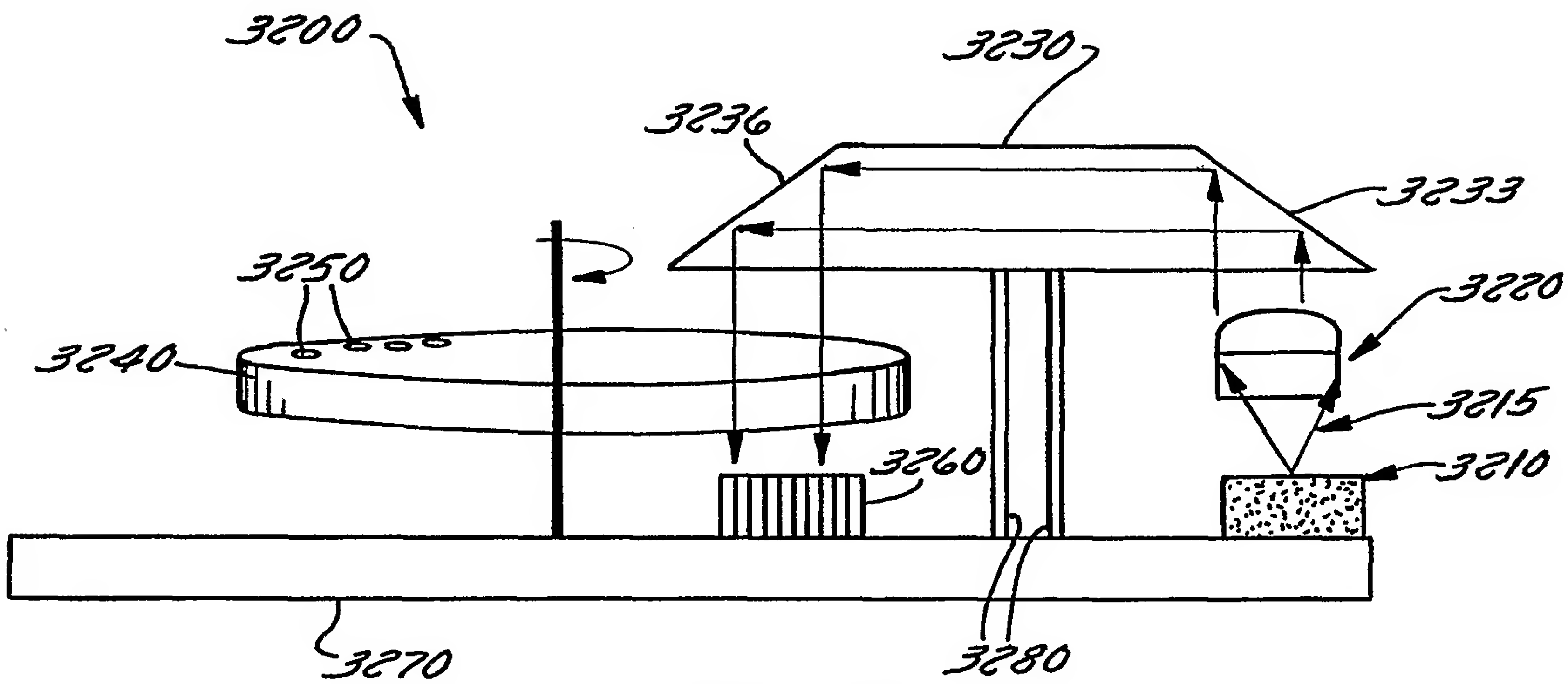
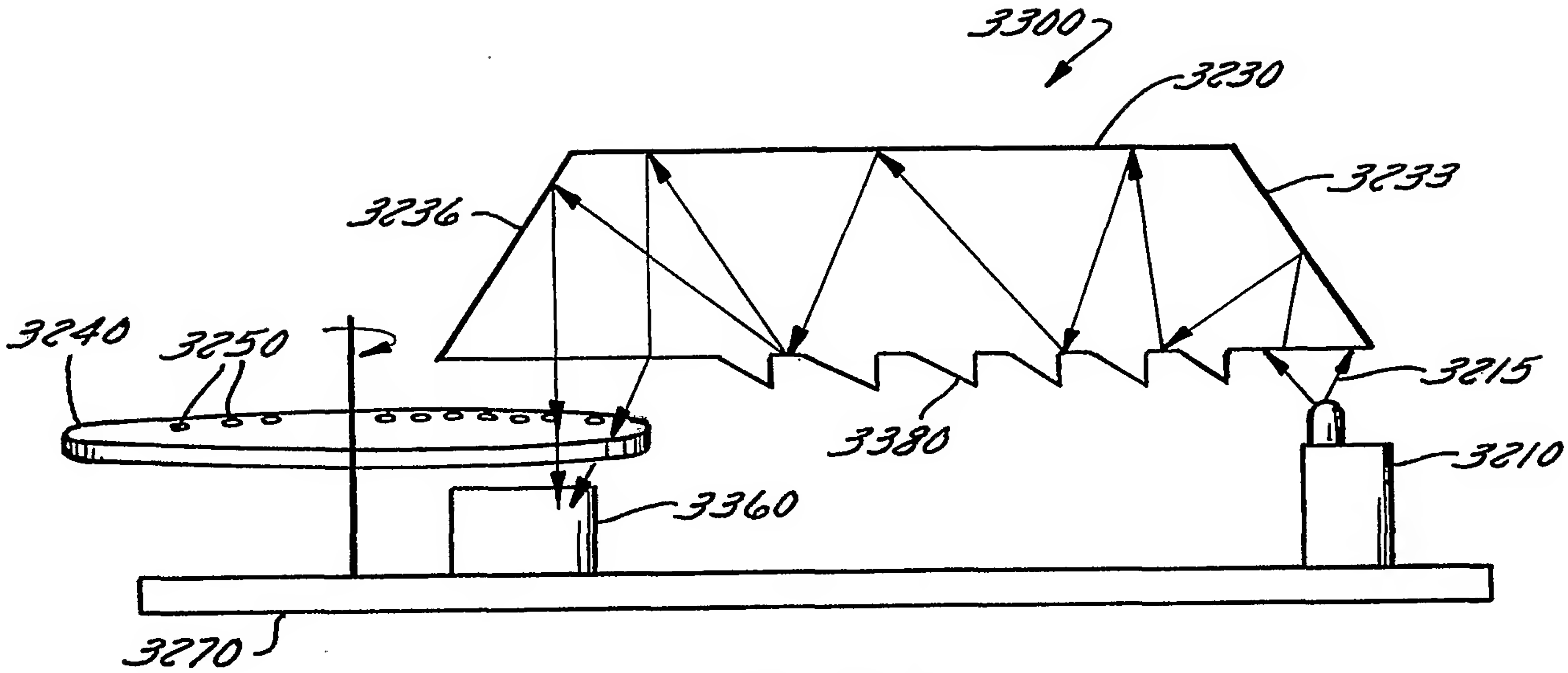

3200
3230
3236
3233
3250
3220
3240
3215
3260
3210
3270
3280

FIG. 32


3300
3230
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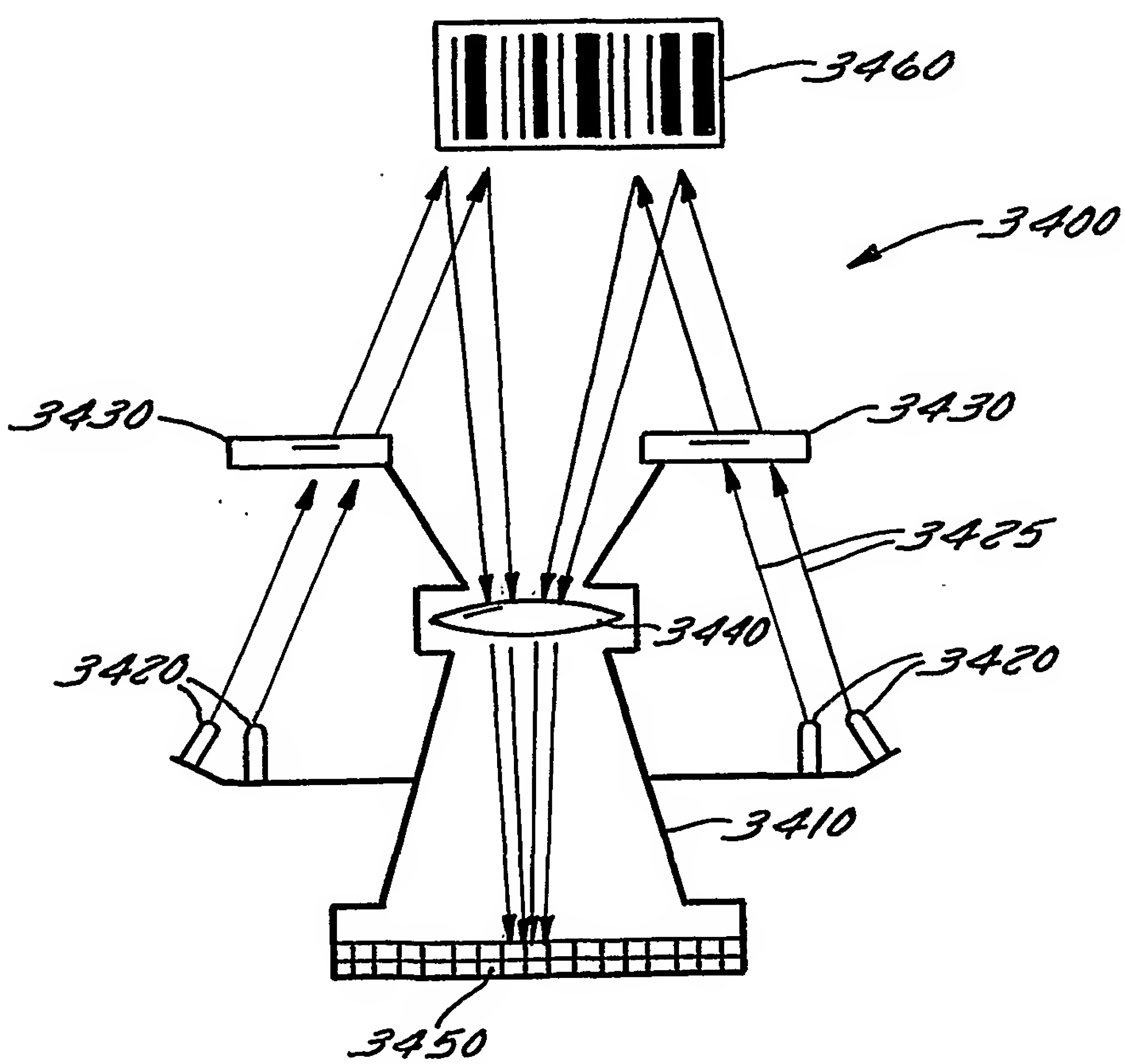
3236
3240
3250
3215
3380
3210
3360
3270

FIG. 33


3460
3400
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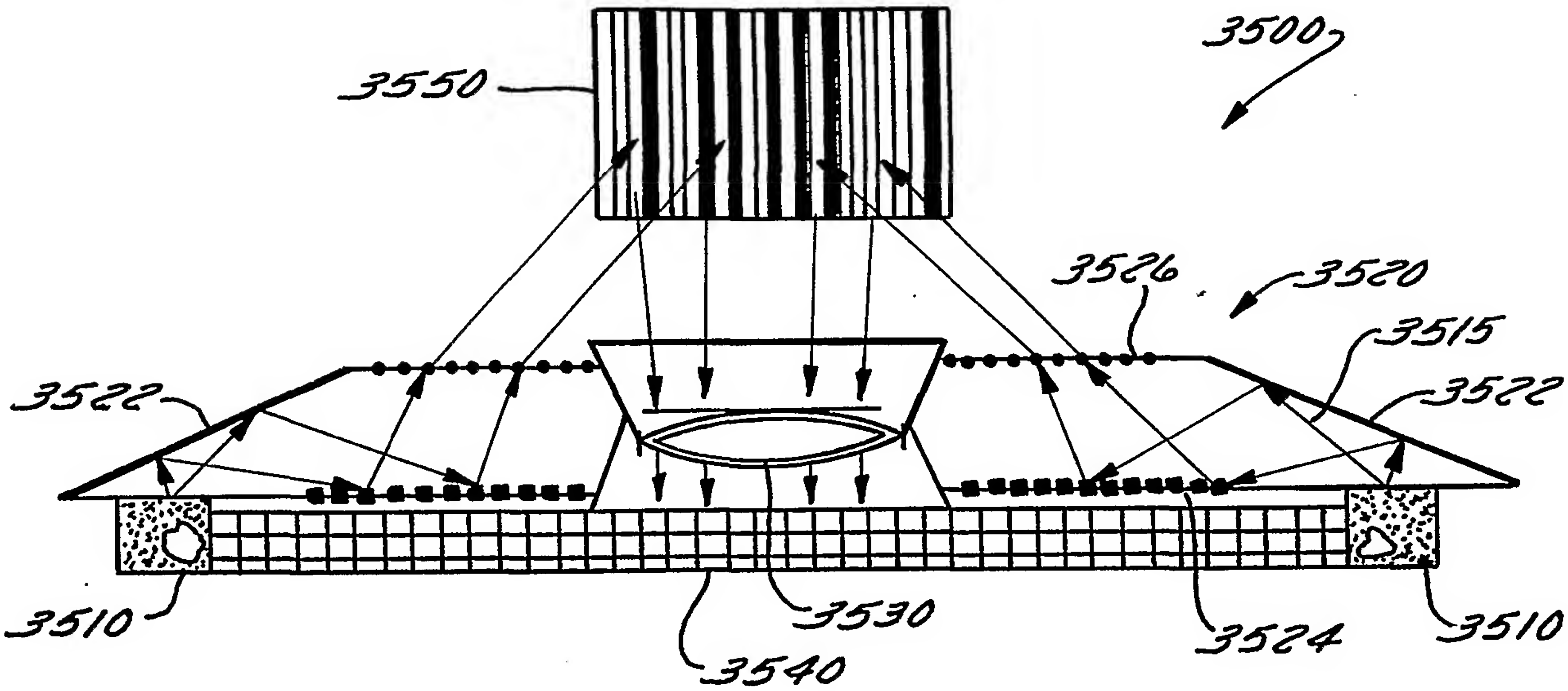
3430
3425
3440
3420
3420
3410
3450

FIG. 34


3500
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3522
3510
3530
3524
3510
3540

FIG. 35

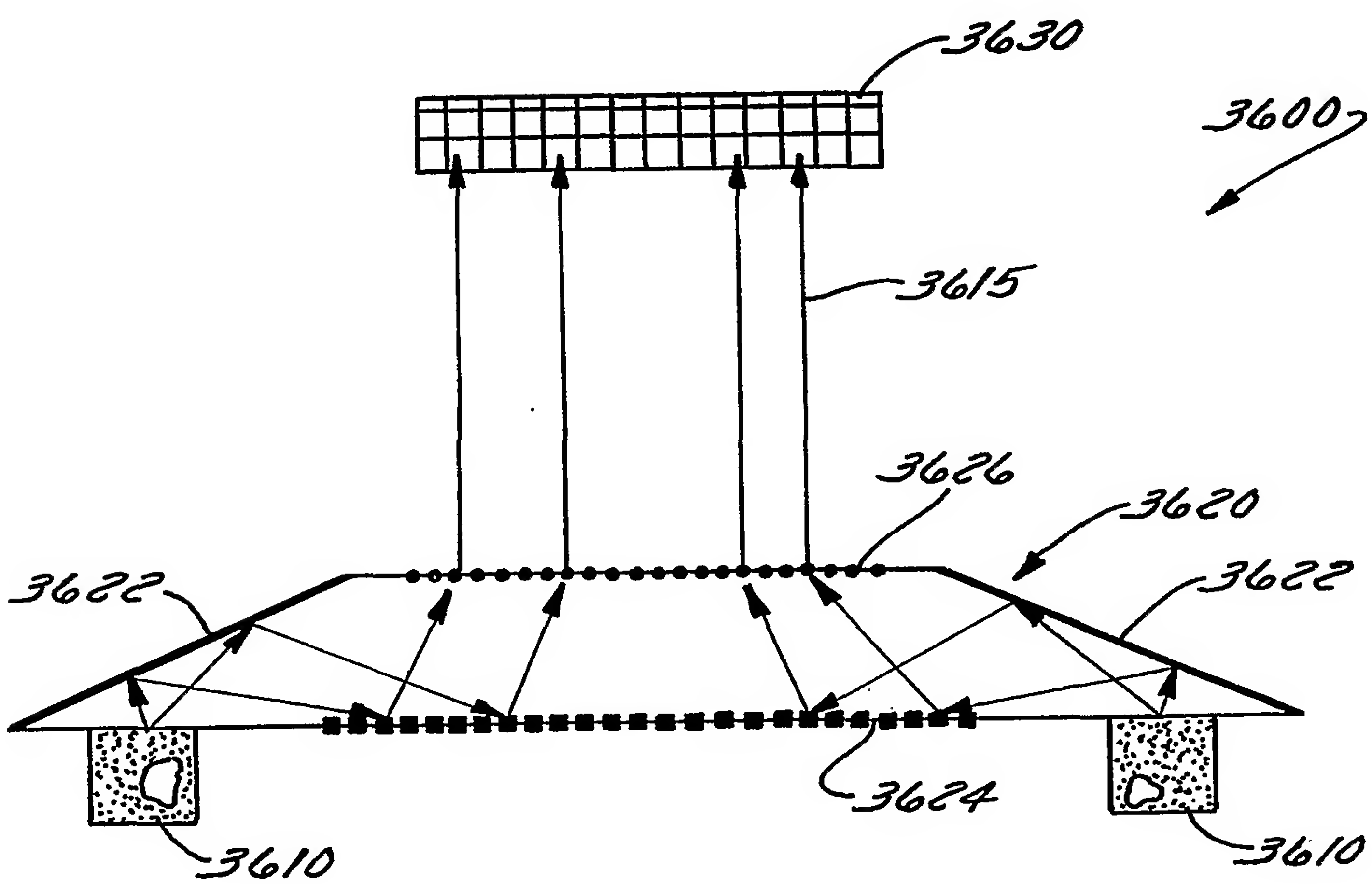
3630
3600
3615
3626
3620
3622
3622
3624
3610
3610

FIG. 36

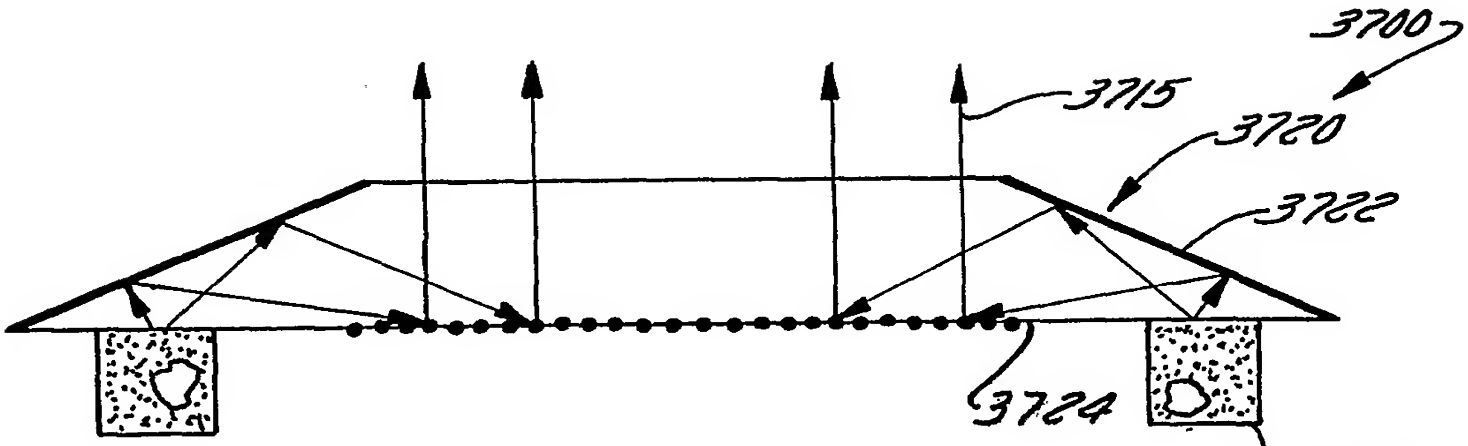

FIG. 37

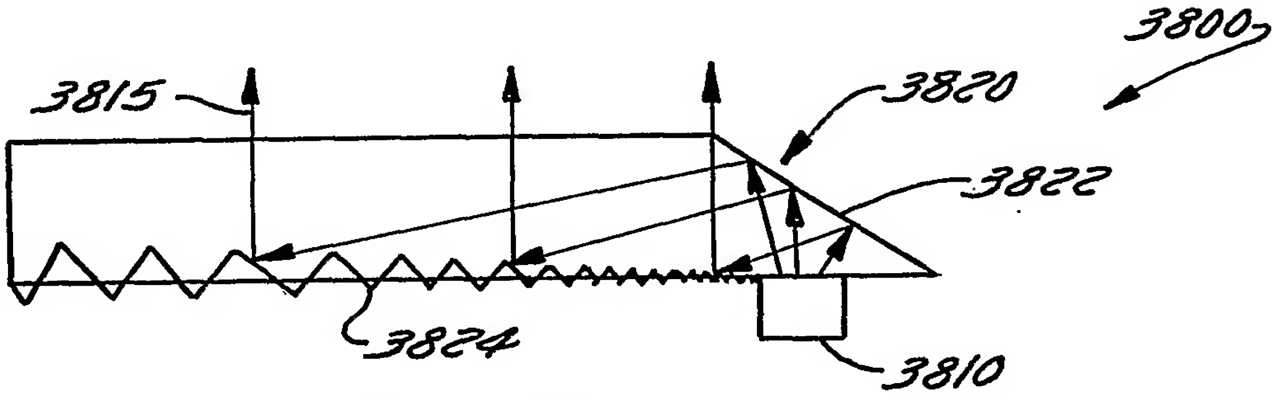

FIG. 38

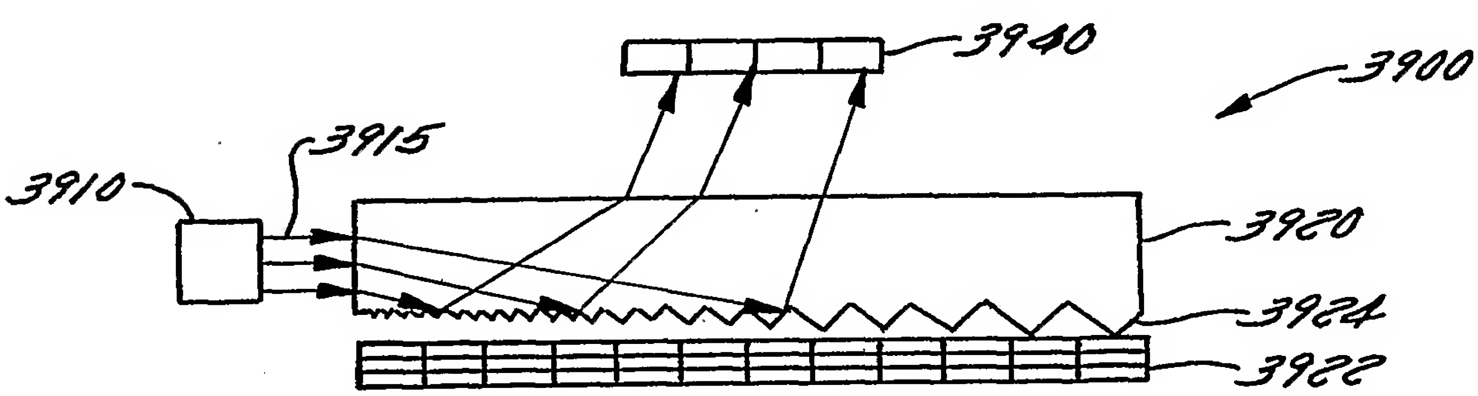

FIG. 39

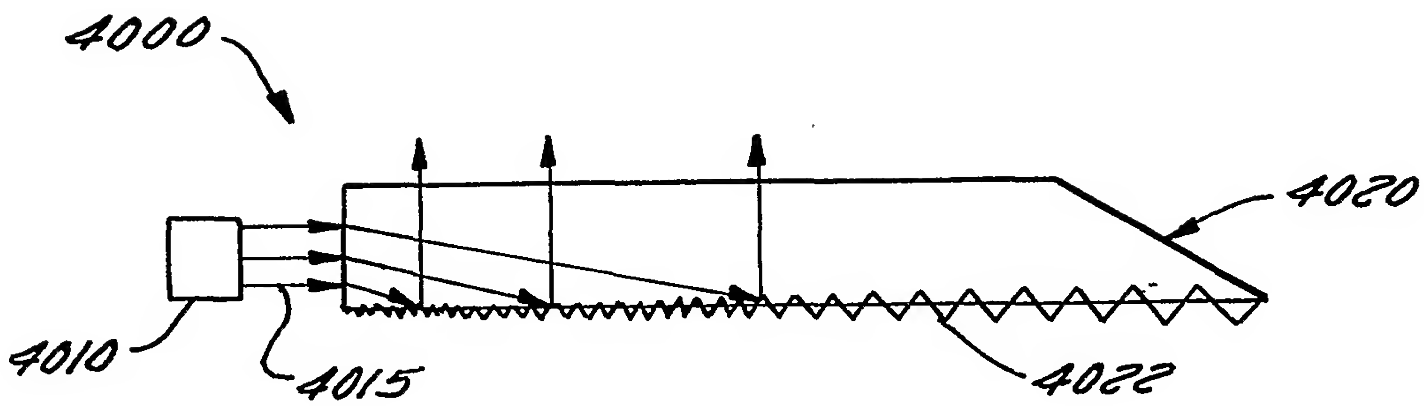

FIG. 40

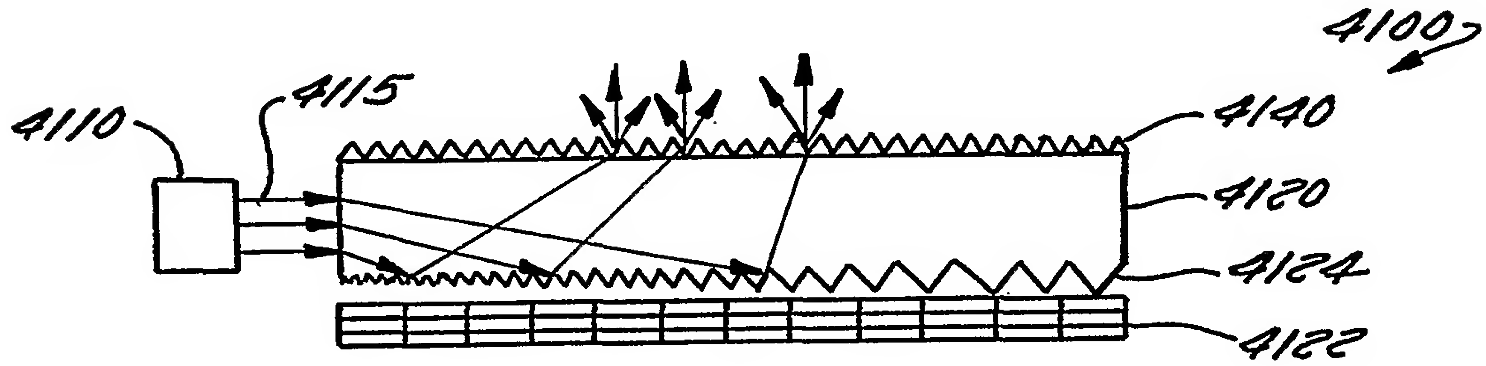

FIG. 41

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/06399

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :G06K 7/10, 7/14
US CL :235/454, 457, 462.01; 362/31, 551; 349/56, 63, 64
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 235/454, 457, 462.01; 362/31, 551; 349/56, 63, 64

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,756,981 A (ROUSTAEI et al.) 26 May 1998 (26.05.1998) figures 1, 5, 49, and 51, col. 42, lines 25-36.	1-6, 8-14, 400
Y,E	US 6,211,930 B1 (SAUTTER et al.) 03 April 2001 (03.04.2001) abstract, figure 2, columns 3 and 4.	7, 18-29
X, P --- Y, P	US 6.130,730 (JANNSON et al.) 10 October 2000 (10.10.2000) abstract, figures 1,7, and 8, col. 5, line 57 - col. 6, line 32, columns 19 - 22.	15-17 --------- 18-42
X ---- Y	US 5,586,212 A (MCCONICA et al.) 17 December 1996 (17.12.1996), abstract, figures 2 and 5, column 3 to column 6.	1,30,39,41 ------------ 2-14, 31-40, 42

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

06 MAY 2001

Date of mailing of the international search report

12 JUNE 2001 (12.06.01)

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